FILE COPY.

IN THE

Supreme Court of the United States

OCTOBER TERM, 1914.

No. 1. Original. In Equity.

THE STATE OF GEORGIA, COMPLAINANT, BY
ITS ATTORNEY-GENERAL,

vs.

THE TENNESSEE COPPER COMPANY AND THE
DUCKTOWN SULPHUR, COPPER AND
IRON COMPANY, LIMITED, DEFENDANTS.

Supplemental Brief for Complainant Upon
Its Motion to Enter Injunction Decree.

WARREN GRICE,
Solicitor for the State of Georgia.

J. A. DRAKE,
Special Counsel.

THE LAW REPORTER PRINTING COMPANY, WASHINGTON, D. C.

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OCTOBER TERM, 1914.

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THE STATE OF GEORGIA, ETC., COMPLAINANT,

vs.

THE TENNESSEE COPPER COMPANY, AND THE DUCKTOWN SULPHUR, COPPER AND IRON COMPANY, LIMITED, DEFENDANTS.

Motion to Complainant to Enter Injunction Decree Against the Defendant, the Ducktown Sulphur Copper and Iron Company, Limited.

Since examining the brief and argument filed on behalf of the Ducktown Sulphur, Copper and Iron Company, Limited, solicitors for the complainant desire to call the Court's attention to certain statements and inferences therein which are not borne out by the record; and also to reply to certain positions taken by them.

We first respectfully direct the Court's attention to certain statements on pages 4 and 5 of our adversaries' brief, relating to the stipulation entered into between complainant and the defendant, the Tennessee Copper Company. This stipulation in full appears already as a part of the record in the original cause, being embraced in the motion for leave to file agreement and stipulation

made by the solicitor for complainant and the solicitor for the Tennessee Copper Company. The reason the State of Georgia is not now asking for a decree to be entered against the Tennessee Copper Company is because of the stipulation into which it entered with the last-named defendant. It is true that under it, the Tennessee Copper Company binds itself to pay certain damages, if found to exist, to the amount of $16,500 per annum, but this is but an incident of the stipulation and by far its lesser ingredient. The main thing is that the Tennessee Company agrees, in Par. 2 thereof, that from April 10th to October 1st of each year, during the life of the agreement, it will not operate more green ore furnaces than it finds necessary to permit of operating its sulphuric acid plant at its normal full capacity. See page 3 of that part of the record submitted on the first day of the October term, 1913.

From April 10th to October 1st is the growing season.

In the testimony recently taken, page 702, a witness of the Ducktown defendant company testified that the Tennessee Copper Company on June 8th and 9th were operating only two green ore furnaces, and this substantiates the complainant's theory that the Tennessee Copper Company is not doing the damage in North Georgia, because it is proven, as already shown, that the Tennessee Copper Company's acid chambers are 1200-ton daily capacity, and are abundantly able to take care of the fumes from two green ore furnaces, otherwise the defendant, the Ducktown Copper Company, is taking care of a much smaller per cent of its fumes than the Tennessee Copper Company, because,

according to their own showing, they can take care of only 130 to 135 tons per day, while they operate one furnace.

But we mainly wish to call the attention of the Court just here to other things in this stipulation, which show that the State in good faith was doing all it could to permit these companies to operate without calling on this Court for its injunctive decree. The brief of opposing counsel, on page 4, recites a portion of the resolution adopted by the General Assembly of Georgia, by which the Governor was authorized and directed to enter into an agreement or stipulation with the Ducktown Sulphur, Copper and Iron Company, Limited, for the same length of time and under the same terms, conditions and limitations as those contained in the agreement with the Tennessee Company, except that the Ducktown Company would only be required to pay as a maximum the sum of $8,500 annually as damages, to be distributed under like terms and conditions, provided damage was shown.

Under this contract an inspector was provided for. The company obligated itself to give information whenever called on by the Governor, a board of arbitration was provided for, and it was not made obligatory upon any citizen to submit his claim to arbitration. Complainant believed that the Tennessee Company had by its equipment then recently installed put itself in position to take care of practically all of these acid fumes, but it was contemplated that in spite of such arrangements small damages from it might arise, and provision was also made for pay for these. This contract, however,

was for a limited time only. The agreement was that if the company did not breach this contract that the State would not apply for an injunction or other relief against the Tennessee Copper Company within three years from October 1, 1913.

Defendants' counsel, in dealing with the evidence of Dr. Hedgecock, on page 41 of their brief, state that he is only a plant pathologist employed by the United States Government, and that he only made flying trips through North Georgia in an automobile, and, on page 42 of their brief, they charge that he shows that he is a prejudiced and an unfair witness. We respectfully submit that the records cited do not sustain any such contention, but, on the other hand, show that he is a most thorough and competent man in his line, and that he is not only a plant pathologist and made plant life a study for the last twenty or twenty-five years, but for the last three years, under the direction of the Government, has made a special study of sulphur dioxide fumes on plant life, and at the instance of the Government visited all the principal copper-producing plants in the United States, not for the purpose of studying the plants and methods of smelting ores, but to make a study of the smelter injuries on forests and growing vegetation, and he qualifies, under the most rigid rules of evidence, as an expert on smelter injury; and through all of his evidence, as cited by defendant's counsel, shows that there is abundant and notorious smelter injury through all the northern section of Fannin County, Georgia, and other counties visited by him, not only in the year 1914, just previous to the taking of the evidence in this investiga-

tion, but before this inquiry was up in 1913, at the instance of the Government he went there and inspected this affected region and testified as to the conditions that then prevailed and which were similar to those that obtained in 1914.

Defendants' counsel, in taking the evidence, gave a great deal of space to the cross-examination of the Shippen Brothers, in an effort to show that they instigated the original suit in this case, and have been responsible for the carrying on of it since by the State. Since seeing defendants' counsel's brief, we find that they are still devoting much space to this matter. We submitted in our original brief that all this cross-examination, wherein more than fifty pages were taken up in the introduction of correspondence between Shippen and certain companies relative to the sale of Shippen Brothers' stock, was incompetent, yet defendants' counsel still are insisting upon this class of evidence. We still respectfully submit that all such evidence is incompetent, but if it could be considered at all the papers read into the record on cross-examination by defendants' counsel show that the Shippen Brothers were not responsible for this litigation, but, on the contrary, both the Shippens state most positively that they were only one in thousands of citizens in North Georgia who were making complaints. The statement is made in defendants' brief (see p. 110), that the State has been imposed on in prosecuting this action, and that it has been used to promote private and selfish interests of individuals; and the inference is that the Shippens control the Governor and the General Assembly of Georgia.

The testimony in the record is to the contrary. The record shows that these two Shippens were, when they moved to Georgia some years ago, experienced timber men. They do own large quantities of timber in the affected districts, and they are naturally in sympathy with the movement to stop the depredations thereon.

The charge is made by defendants' counsel, on page 113 of their brief, that W. H. Shippen caused Shippen Brothers Lumber Company, in 1908, immediately after the original decree in this case, to be called together and sell to the Tennessee Copper Company a perpetual easement over the Shippen Brothers Lumber Company's lands in North Georgia, which amounted to something like 100,000 acres, for a consideration of $50,000. This charge is not only not sustained by the evidence as cited by defendants' counsel, but, on the other hand, said evidence shows that W. H. Shippen protested against this settlement, and would have nothing to do with it, advised against it, and when he saw he was outvoted by the other directors, he got up and left the room mad, and would have nothing whatever to do with such settlement. All that the correspondence referred to by defendants' counsel, on pages 13, 14, and 15, of their brief, proves is that the Shippen Brothers were trying to protect themselves against damage which was being done to their timber interests, and such damage was recognized by the Tennessee Copper Company, else they would never have paid the sums of money they did for these easements. Page 333, Complainant's evidence; page 520. This last citation shows that this witness, whom our adversaries would have this Court believe was

in league with the Tennessee Copper Company, vigorously opposed the Shippen Brothers Lumber Company's entering into this settelment with the Tennessee Copper Company, and vigorously opposed granting them an easement to emit smoke and fumes over their timber. The language of the witness is:

> ". . . I did everything in my power, as I testified heretofore, to prevent my company from executing that contract with the Tennessee Copper Company at the figure at which it was executed. We had a perfect row in our meeting there. I insisted that we not make any settlement with them at all, that we grant an easement in that property at no figure less than $100,000, which should be named for the damage at that time, but they thought differently, and after I left them and came back into the meeting they had suggested the figure of $25,000 for the damages, and I insisted on their raising that figure and finally got them to raise it to $50,000."

Opposing counsel, on page 117 of their brief, use this language:

> "It is also worthy of note that this same Professor McCandless recently testified herein that there were no damages of consequence resulting from the operations of the Ducktown Company since its acid plant was installed."

McCandless testifies to no such thing. Their citation to support the statement in the brief is to the evidence, Vol. I, pages 385 and 389. The reference is in-

accurate. However, no such deduction can be made from this witness's testimony anywhere in the record. His testimony will be found on page 836. Here is a man whom they highly compliment in their brief. They put him on the stand. It is shown that he was familiar with conditions at the time this suit was instituted and nowhere did they ask him, when they put him on the stand, his opinion as to how conditions of today in North Georgia compare with those of 1906 and 1907. He has not been State chemist for several years. Recently it appears he has been doing work for the Ducktown Company. On page 836 opposing counsel asked Dr. McCandless as to changed conditions in Fannin County, Georgia, and he answered there was a marked improvement in the conditions, and he observed this on a visit in April, 1908. This is the only place Dr. McCandless states that the conditions have improved, and this the opposing counsel quote from Dr. McCandless as evidence for the defendant, the Ducktown Copper Company. Opposing counsel use this statement of Dr. McCandless to try to impress the Court that conditions are improved in North Georgia since the installation of the acid chambers, when the facts are, as proven by the defendant, that there were no acid chambers in operation by either company at the time Dr. McCandless speaks of improved conditions in April, 1908. The facts are, as shown by Mr. Lamoreaux, that the Tennessee Copper Company started its acid plant in September, 1908, but he says the same was not a success (Rec., p. 802), and that the Ducktown Company, the defendant in this investigation, started their acid plant

in the spring of 1909 (Rec., p. 808). So, at the time Dr McCandless speaks of the improved conditions, neither company claimed to be taking care of any of the fumes, and conditions were identical with those obtaining at the time of the original decree in this cause.

In one place it appears on the surface that Dr. McCandless did say that it is impossible for the smoke or fumes of the Ducktown Company to do any damage in Georgia, but when the Court reads his evidence it will be noted that he makes that statement in response to a hypothetical question, wherein it is assumed that the smoke fumes from the Ducktown chinneys as soon as they are emitted take a cone shape, with the apex pointing toward the top of the stack and resting upon the stack, and that as the cloud of smoke moves toward Georgia it widens so that the mouth of the cone would be five miles wide by the time it reached Georgia. On this assumption, Dr. McCandless answered that the fumes be so diluted that it would be impossible for them to do damage. The trouble about this question and this answer is that the smoke does not come out in a cone shape, nor does it assume a cone shape, but the testimony is directly to the contrary. All the witnesses who testified at all on this subject agree to our statement as to this. The other side did not put up a witness to prove that the smoke took a cone shape, with the mouth of the cone gradually widening. On the contrary, the proof is all one way as to this, to wit, that the particles of the smoke seem to have an affinity one for the other, just like all other smoke, and that it travels in a solid mass until it comes in contact with sides of the

mountains or some other object, which causes it to break up.

On pages 17, 18, and 19, of the brief filed by the other side, they refer to statements in the form of brief filed on behalf of this complainant, wherein the Tennessee Copper Company are referred to as the "chief offender." In the beginning it was probably correct to characterize the Tennessee Copper Company as the "chief offender." That, however, was done in an argument presented to this Court in 1905—ten years ago. This record shows that this is not true now, for, as we pointed out in our main brief, in May, 1913, when the Tennessee Copper Company was closed down and not melting any ores of any kind, and the Ducktown Company was in operation, there were great quantities of sulphur smoke in North Georgia, and immediate, visible injury following such visitations of smoke. This could not possibly be attributed to the Tennessee Copper Company. This fact was established by six witnesses, as pointed out on page 20 of complainant's original brief in this investigation. Further, in July, 1914, on the 1st, 2d, 3d, and 4th days of July, at which time it was proved that the Tennessee Copper Company was closed down and that the Ducktown Copper Company was in operation, there were great quantities of smoke in North Georgia, at some places more than had been seen in years, and it was so strong that it would be smelted; and immediately thereafter there was smelter injury visible upon the forest garden and farm products. This fact was established by twelve witnesses (pp. 20 and 21 complainant's brief).

Our proof was abundant that the damage is now being

done by the Ducktown Sulphur, Copper and Iron Company. And, further, in substantiation of this contention, we call the Court's attention to the evidence of Dr. Hedgecock, on pages 8 and 17 of complainant's evidence. On page 17, Dr. Hedgecock makes the following statement:

> "From my observations last year that I made of the smoke columns from the two smelters, I observed the height and direction of the two columns, the direction which they were going, and as to how each struck the hills, and I noticed that the Ducktown column usually struck the hills at a lower altitude than the one from the other plant."

On page 8, Dr. Hedgecock says, in speaking of the Ducktown smoke's carrying qualities:

> "From my observations from the smoke columns I have seen I would judge it would carry out six or eight or ten miles, depending on conditions, it might go further."

In answer to a question as to how far the injurious effects of the Ducktown smoke would be observed in Georgia, he says:

> "It would pass out within a radius of from 6 to 15 miles from Ducktown" (Rec., p. 7).

A further significant fact, we would respectfully call the Court's attention to, is this: After the State of Georgia had completed its evidence, the defendant came before this Court, and asked permission to take rebuttal evidence, after the time for taking evidence as originally fixed by the Court had closed, and in the mo-

tion to take rebuttal evidence one of the main grounds set up was the fact that they were taken by surprise, by this identical proof that the State had proven damages in May, 1913, and July, 1914, when the Tennessee Copper Company was closed down; yet, when they came to take their rebuttal evidence, they failed to put up a single witness from North Georgia or elsewhere who would state that there was no smoke in Georgia on July 1, 2, 3, and 4, 1914, and in May, 1913, on which dates the complainant proved smoke and damage in Georgia.

It is a fair statement to make that the defendant, against whom we are now proceeding, charges that the Shippens are solely responsible for this suit, and that the Shippens are seeking to protect the Tennessee Copper Company, and that the two are endeavoring, through the State, to put all the blame on the Ducktown Company, whereas the Ducktown people say that the Tennessee Company is responsible for the present damage. If this were true, it is indeed remarkable. Complainant only called one witness from the camp of the Tennessee Copper Company, to wit, Mr. Panhorst, and used him for the sole purpose of showing that on certain dates the Tennessee Copper Company plant was closed down. We necessarily had to go to one of their employees to get this fact. When we had proven it by this witness, we turned him over to the other side, and they gave him a lengthy cross-examination, which was in the way of an examination in chief, and he made them a valuable witness, testifying, in effect, that he had traveled extensively in North Georgia and had not seen any smelter injury.

If this Court will bear in mind one well-known fact, which is undisputed in this record—a fact to which many witnesses testified on both sides—all, or nearly all, of this entire testimony can be harmonized. That great fact is this: That the effects of these sulphur fumes are not uniform, and that they do not go in a uniform course; there are many things that cause them to change their course and direction—the intervention of a hill will deflect them as will the change of air currents in the mountains. It is shown they will settle in one cove, or a part of one cove, and blight and wither one field of corn, and another field within a hundred yards of it will not be affected at all. It will skip over another farm and do no injury, and the next adjacent farm may be damaged seriously. It may then rise and travel eight or ten miles and do no damage, and settle in a cove at that distance and do serious harm; that the conformation of the hills and the mountains has a great deal to do with the injury. For instance, east of these plants it has never been known to injure anything for more than three or four miles, on account of a high range of mountains. To the west, except for one break, and to the northwest it is almost the same way; and to the southwest, after going six to seven miles, there is no damage, because the Blue Ridge Mountain comes across and the smoke, if it crosses it, goes so far before it settles again that it is diffused until it does no harm; but, going to the south and southeast from these plants there is a break and gaps in the mountain, and up the Toccoa River into Georgia there is a break in the mountains, and the smoke, as is proved by all the evidence, follows these depressions and

the air currents follow these depressions in the mountains and these are the causes, as given by the experts, of these conditions as to injury.

The testimony that this injury has occurred and is now occurring, and that it happens in many places, and that the damage is great and continuing and directly traceable to the Ducktown Copper, Sulphur and Iron Company is proved by a host of witnesses who own timber and farms in North Georgia within the zone affected, and it is also established abundantly and directly by the impartial and thoroughly competent witnesses Hedgecock, Clarke and Johnson, Government experts whom, although they are assailed in the brief of our adversaries, will, we feel confident, be considered by this or any other court as men of character and intelligence.

All of which is respectfully submitted.

WARREN GRICE,
Solicitor for Complainant.
J. A. DRAKE,
Special Counsel.

Office Supreme Court, U. S.
FILED
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JAMES D. MAHER

No. 1, ORIGINAL

IN THE

Supreme Court of the United States

OCTOBER TERM, 1914

THE STATE OF GEORGIA,
Plaintiff.

vs.

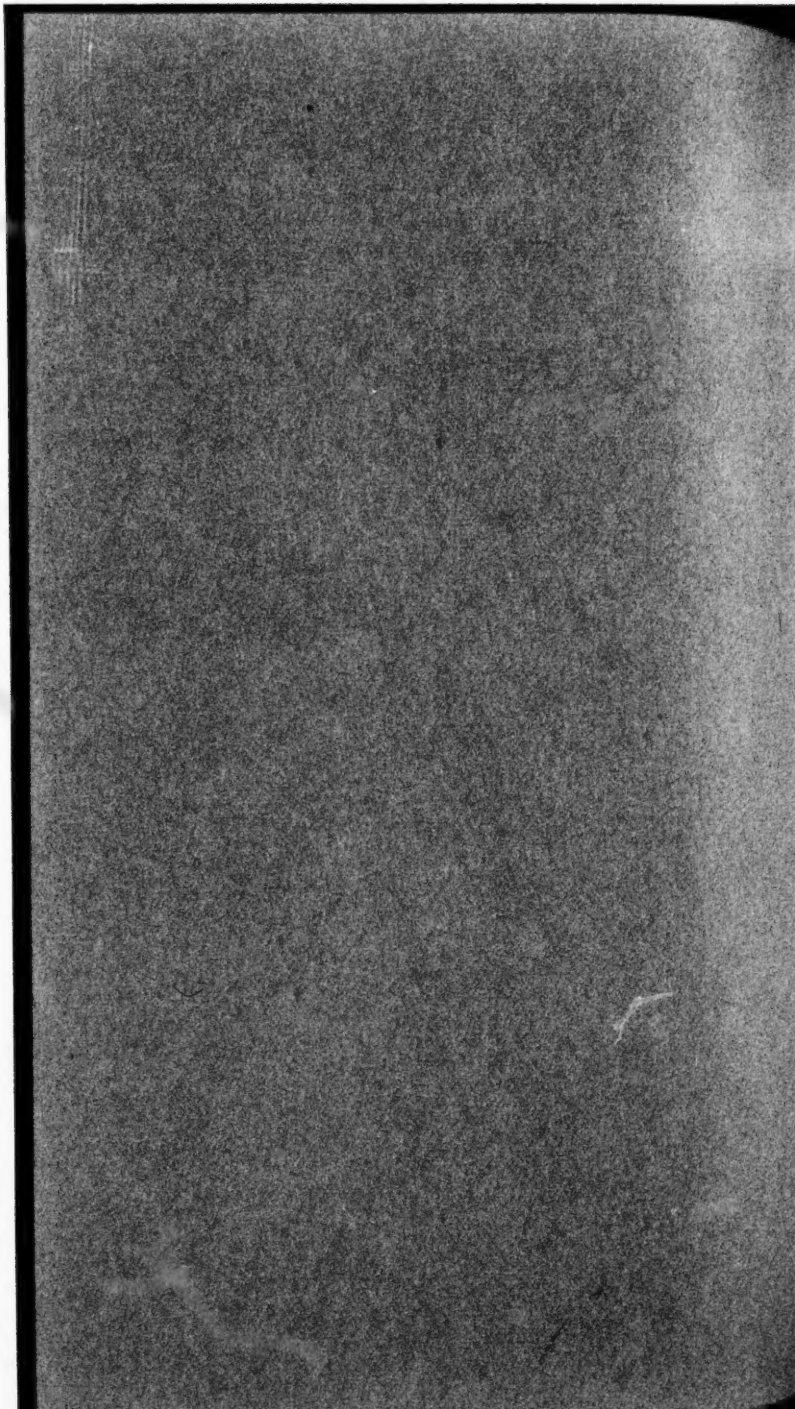
THE TENNESSEE COPPER COMPANY
and
THE DUCKTOWN SULPHUR, COPPER AND IRON COMPANY, LTD.
Defendants.

IN EQUITY

Supplemental Matter and Exhibits Submitted Upon Leave Granted at the Hearing on Behalf Ducktown Copper Company.

W. B. MILLER,
J. A. FOWLER,
Solicitors for Ducktown Sulphur, Copper & Iron Company, Ltd.

MACGOWAN-COOKE PTG CO., CHATTANOOGA



No. 1 ORIGINAL.

In the Supreme Court of the United States

OCTOBER TERM, 1914.

THE STATE OF GEORGIA, *Plaintiff*,

vs.

THE TENNESSEE COPPER COMPANY AND THE DUCKTOWN SULPHUR, COPPER & IRON COMPANY, LTD., *Defendants*.

IN EQUITY.

Supplemental Matter and Exhibits Submitted Upon Leave Granted at the Hearing on Behalf Ducktown Copper Company.

To the Honorable Court:

There is shown below, Exhibit No. 1 to the witness Lamoreaux's deposition (Vol. 2, p. 805-6) setting forth tonnage of ores smelted by the Ducktown Company each year from 1907 to 1913, inclusive. The company has four mines, only two of which (the Mary and East Tennessee) were operated during the entire period. This Exhibit also shows total sulphur content of the ores by years, the total sulphuric acid yield since the acid plant began operations in June, 1909; likewise the yield of copper matte. This company does not refine its matte, and thereby expel all the sulphur, as does the Tennessee Copper Company. It sells the matte to a refinery in New Jersey.

Exhibit No. 1 to Testimony of W. F. Lamoreaux.
(Vol. 2, p. 805-6.)

MARY MINE ORE.

YEAR	TONS OF ORE	PERCENTAGE OF SULPHUR	TONS OF SULPHUR
1907	181,473.4	18.87%	34,244.03
1908	142,234.8	17.90%	25,460.03
1909	139,549.7	16.89%	23,569.94
1910	118,558.25	16.55%	19,621.39
1911	122,873.1	16.84%	20,691.83
1912	162,696.2	17.87%	29,073.81
1913	126,074.9	20.86%	26,299.22

CALLOWAY MINE ORE.

YEAR	TONS OF ORE	PERCENTAGE OF SULPHUR	TONS OF SULPHUR
1907	714.0	13.21%	94.32

EAST TENNESSEE ORE.

YEAR	TONS OF ORE	PERCENTAGE OF SULPHUR	TONS OF SULPHUR
1907	670.4	12.00%	80.45
1908	551.3	12.00%	66.16
1909	2,010.9	12.00%	241.31
1910	5,165.2	13.13%	678.19
1911	20,634.8	10.36%	2,137.76
1912	14,157.6	12.86%	1,820.67
1913	21.563.0	9.32%	2,009.67

ISABELLA MINE ORE.

YEAR	TONS OF ORE	PERCENTAGE OF SULPHUR	TONS OF SULPHUR
1910	4,885.9	29.45%	1,438.90
1911	1,850.7	30.20%	558.91
1912	5,271.4	29.90%	1,576.15
1913	4,611.5	31.97%	1,474.30

MATTE SHIPPED.

YEAR	POUNDS OF MATTE	PERCENTAGE OF SULPHUR	TONS OF SULPHUR
1907	13,433,156	22.85%	1,534.74
1908	10,000,127	22.67%	1,133.51
1909	10,167,245	22.43%	1,140.26
1910	9,193,545	22.91%	1,053.12
1911	10,476,119	22.32%	1,169.13
1912	11,029,575	22.20%	1,225.39
1913	12,537,045	22.13%	1,387.22

60° Be′ ACID SHIPPED.

YEAR	TONS OF ACID	PERCENTAGE OF SULPHUR	TONS OF SULPHUR
1909	12,975.90	25.4%	3,295.87
1910	47,473.53	25.4%	12,058.27
1911	45,626.03	25.4%	11,589.01
1912	48,126.40	25.4%	12,224.11
1913	48,852.05	25.4%	12,408.42

Note: The above Exhibit does *not* show the sulphur content in the slag, flue dust and sulphur flowers, all of which, all witnesses agree, is eliminated or precipitated immediately at the plant. Nor does it take into account the "escapes" of sulphur dioxide around the smelters.

But approximate correctness of each year is shown by comparing it with 1913, which Mr. Lamoreaux analyzed thus:

Mary Mine yield of sulphur was	26,299.22	tons
Add to this from East Tennessee ore	2,009.67	"
Further add Isabella yield	1,474.30	"
Total sulphur eliminated	29,783.19	"

The distribution of this total sulphur is shown best by literal quotation from Mr. Lamoreaux' testimony explaining this Exhibit (Vol. 2, p. 813).

> "For example, suppose we take 1913; there was contained in the ores treated 29,783.19 tons of sulphur. Now, of that sulphur content in the ore 1,387.22 tons went into the matte which was shipped away; 12,408.42 tons of sulphur went into the sulphuric acid which was shipped away; 2,536.3 tons of sulphur was contained in the slag which was thrown away; and 348.7 tons of sulphur was carried out of the furnaces in the form of flue dust. The sum total being 16,680.64 tons of sulphur accounted for
>
> "Q. 51. How much sulphur was accounted for?
>
> "A. 16,680.64 tons.
>
> "Q. 52. How much sulphur did that leave that was not accounted for?

"A. 13,102.55 tons.

"Q. 53. As compared with 16,680.64 tons?

"A. There were 16,680.64 tons accounted for, and there were 29,783.19 tons in the original ore.

"Q. 54. Then you saved, according to those figures, something over half the sulphur?

"A. Yes, sir."

As we recall, General Drake stated in argument that less than 50% of sulphur was reclaimable, according to the most approved processes; and that the contracts between the State of Georgia and the Tennessee Copper Company were negotiated on that basis.

The Lamoreaux Exhibit above is for years, but in fact during the growing months the tonnage of ores smelted and sulphur eliminated is much smaller than during the winter months, in an effort to avoid all possibility of injury to vegetation and crops, either in Tennessee or Georgia. (Vol. 2, p. 817).

In response to the suggestion that all the original books pertaining to the years in question, and of which the Lamoreaux Exhibit is a summary, should have been filled and sent up, the following extract is quoted:

> "Mr. Miller: I will state that, as I understand, the State Chemist of the State of Georgia is here present, Mr. Stallings. I never met him until today. I am told he is a man of strict integrity, and I now invite him and General Drake, and any one else who wishes to see the books, to go to Copperhill and there see them as long, and go through them as long, as you may desire—but it is utterly impossible to load all those books in a car, for years past, and bring them down here. You are perfectly welcome to look through them; I understand Georgia representatives

have looked through them repeatedly, and I extend a most hearty invitation to you to go again.

"Mr. Drake: I would be glad to do that and no doubt the State Chemist of Georgia would be glad to do the same, but on account of the limited time at our disposal we cannot; therefore, we would like to have the books present.

"Q. 95. I understand the Chemist of the State of Georgia, and other agents, have had access to the books and have been shown through them on their visits to Ducktown?

"A. They have on two or three visits there been offered every facility; we allowed them every opportunity to view the works and inspect our books and records, and we will only be too glad to have them do so.

"Q. 96. Did any representative of the State of Georgia—were they ever refused any information asked for?

"A. No, sir; to my knowledge, never. It has been the policy of Mr. Renwick to offer them every advantage and any information which they might wish or require.

"Q. 97. You hold yourself ready to do that at any and all times?

"A. I do; yes, sir; those are my instructions.

"Q. 98. I will ask you to state if you have brought with you here, from the books as recorded in the usual course of business, the tonnages of ore smelted and the sulphur content—commencing with 1907 down to date?

"A. I have such figures obtained personally, before leaving Isabella." (Vol. 2, p. 805).

"Mr. Drake: I except to each question for the reason I have stated before that the books are the best evidence."

Exception overruled and appeal taken.

"Q. 99. Have you prepared a synopsis showing the tonnage of ores smelted by years, from 1907, the percentage of sulphur and the total yield of sulphur since coming to Chattanooga?

"A. I have.

"Q. 100. I will get you to file that as Exhibit No. 1 to your testimony?

"A. I do so."

"Mr. Drake: We except to that because the books are the best evidence."

Exception overruled and appeal taken. (Vol. 2, p. 805-6).

Note: Mr. Stallings, the Georgia State Chemist, referred to above as present at the hearings, was not called as a witness. Dr. McCandless, former State Chemist, who had repeatedly visited the plant and inspected the company's books, testified:

"Q. 30. You speak of the books having been submitted to you. I will ask you to state if they appeared to be regularly and accurately kept in the ordinary course of business?

"A. Yes, sir.

"Q. 31. On the occasion of your visit to this company's office as a representative of the State of Georgia, or in any capacity, I will ask you if there was the slightest hesitation to give you the information for which you asked, or any disposition on their part to conceal anything?

"A. No, sir; no, sir.

"Q. 32. All means of information were offered you and your parties?

"A. Yes, sir." (Vol. 2, p. 839).

Mr. W. M. Bowron, commissioned by Governor Brown, of Georgia, as an expert to examine the Ducktown Company's plant (Vol. 2, p. 771) exhibited and testified to the correctness of his report to the Governor (filed as Exhibit A to his affidavit October Term, 1913), in which report he deals with the output of the company by years from 1901, and recites:

> "These details have been kindly furnished me by Mr. C. W. Renwick, resident manager . . . . . I went unannounced and from the top of the hill overlooking the plant . . . . . In other words as the smelter records show, they cut down their output to about what they could take care of in the way of sulphurous acid fumes or smoke. They have a well built acid plant working perfectly when I went over it and took care of the sulphur dioxide as formed." (Ib., p. 45-6).

It thus appears from the undisputed evidence that as compared with 1907, the result as to sulphur elimination, reclamation, conversion, etc., is: In 1907, 34,418.80 tons of sulphur was eliminated, and barring the content of the matte, slag, flue dust and sulphur flowers, the whole thereof was expelled from the present smelter stack. In 1913, but 13,102.55 tons could possibly have been expelled, as all the remainder was definitely accounted for, (Vol. 2, p. 813), or a difference of 21,316.25 tons. This recovery of much more than 50% of the sulphur content has been accomplished only after immense expenditures and application of most approved methods and machinery in an endeavor to comply with the former ruling of this Court. (Vol. 2, p. 796-7).

The Ducktown Company began smelting in 1891, (Vol. 1, p. 556), and the Tennessee Copper Company began ten years later, that is in 1901. (Vol. 1, p. 559; Vol. 2, p. 626).

From the beginning, the output, smelter stack and quality of ores treated by the Ducktown Company were practically the same—yet up to the advent of the Tennessee Copper Company in 1901-2, there was no damage within the State of Georgia. This is emphasized by the hundreds of affidavits filed with "Argument and Exhibits on Application for Restraining Order" by plaintiff at the October Term, 1905. By actual count of affidavits thus submitted, *eight hundred and nineteen* (819), contain the stock phrase, or its equivalent:

> "During the *past two or three years* great quantities of timber has been killed within the locality in which deponent resides."

Note: We have been able to procure but one copy of the affidavits then exhibited, and they are herewith transmitted as a part of the Volume, entitled "Argument and Exhibits on Application for Restraining Order" filed by counsel for plaintiff at the 1905 Term. Many of the affidavits contain in words or substance, the following:

> "The smoke fumes and gases causing the damage are originated by the Ducktown Sulphur, Copper & Iron Company and the Tennessee Copper Company, the latter, however, being located much nearer the Georgia line and producing by far the largest amount of copper, causes the larger part of the injury." (Ib. 170).

Especial reference is made to the operations of the Tennessee Copper Company effecting Georgia territory, in the report of the Commission of August 30th, 1905, to the Governor urging him request the Attorney General "immediately begin proper legal proceedings to abate said nuisance", which commission consisted of the Commissioner of Agriculture, the State Geologist, Dr. John M.

McCandless, State Chemist, J. R. Chastain and Will H. Shippen, President of Shippen Brothers' Lumber Company. (Ib. 171-5).

Frank E. Shippen, Vice-President of the Shippen Brothers Company, gave an affidavit in November, 1905, wherein he stated:

> "Up to about three years ago the forests owned by said company were apparently healthy and the trees normal, but during the latter part of 1902 and the beginning of 1903 an unhealthy condition was becoming apparent in certain localities near the Ducktown territory and along the water courses radiating therefrom." (Ib. 224).

Will H. Shippen made an affidavit in April, 1906, from which the following extracts are taken:

> "The first time deponent's attention was called to the damage being done to the fruit in these counties by these fumes was some two years ago in deponent's orchard at Ellijay. . . . .
>
> "When deponent first came in contact with said forests and timber in said county some eight years ago they were healthy and thrifty as could be found anywhere, while at present in many parts of said county conditions are the very reverse, etc. . . . .
>
> "I had never noticed the presence of these fumes in the country much before the last two or three years, and there was not much timber or vegetation killed in the forests except from usual and natural causes, but since this gas has made its appearance here great quantities of timber have died. . . . .
>
> "This destruction is fast spreading and reaching further and further into the territory of this State and if the amount of sulphur as now smelted is trebled by blowing in four new furnaces that the Tennessee Copper Company have blown in lately

and are to blow in, the damage will be multiplied in the same ratio. . . . .

"If all these fumes are to be concentrated in a stack 325 feet high and three times more ore treated as heretofore, it is only a matter of a short time until the forests and vegetation in these counties is practically ruined and destroyed. . . . .

"This deponent knows that the damage and the principal destruction to the timber and farming interests of this State has been brought about and accomplished largely in the last two or three years and doubly so in Gilmer County during and since last summer.

"Deponent knows that since the adoption of the new process by the Tennessee Copper Company in the early summer of last year that the presence and strength of the sulphur fumes has been much more marked and the destruction of timber and vegetation more than doubled throughout this territory. . . . .

"This deponent is of the opinion that the 325-foot stack of the Tennessee Copper Company will in no wise relieve the situation, and on the contrary will only increase the destruction of timber in the territory of this State." (Ib. 270-281).

The above are the same witnesses, Frank E. Shippen and Will H Shippen, to whom attention is called in our brief, pages 109 to 121.

The Ducktown Company, during the old days of open heap roasting, expelled a goodly portion of sulphur dioxide from the top of the same stack it has ever since continued to use. (Vol. 1, p. 559; Vol. 2, p. 798). It formerly operated two furnaces, while now it operates but one in the growing season. (Vol. 2, p. 627).

The Tennesse Company from 1901-2 operated with a 150-foot stack, and in 1906 blew in its 325-foot stack, (Vol. 2,

p. 627), and *at that time* practically all of the witnesses agree the chief damage south of the Georgia line began.

Note: Of the "thousands" of affidavits secured by the witness, Shippen, in support of complainant's contention, by actual count *eleven hundred and eleven* (1111) filed at the October Term, 1906, contain, in words or substance, the following stock statement:

> "Within the past two or three years the furnaces of defendants have been smelting enormous amounts of sulphurous copper ore. . . . .
>
> "Particularly has this been the case during the spring and summer of this year, while heretofore, viz., prior to May, 1906, these fumes were rarely ever noticed in deponent's neighborhood except late at night and early in the morning, but since this time these fumes have been present at times at all hours of the day and night whenever the wind was from the direction of the defendants' mines. . . . .
>
> "Since the above spring and summer the fumes seem to have been given an increased carrying power and seem to have been condensed and concentrated and made far more deadly. They seem to have mounted into higher altitudes and be able to pass barriers of mountains and hills that hitherto seemed to protect certain sections where no damage had heretofore appeared. . . . .
>
> "The destruction to timber, crops and orchards has been far greater during the spring and summer of 1906, and the territory so destroyed vastly widened and increased from anything ever before known. Each deponent knows of his own knowledge that since May of this year the destruction of timber and vegetation has been multiplied many times over anything ever before experienced, and such destruction has been wrought and accomplished in much

less time." (See "Supplemental Evidence and Exhibits on Application for Restraining Order" filed by Plaintiff October Term, 1906, pages 1 to 3).

Note: There is but one copy of this supplemental evidence, so far as we know, and it is submitted herewith. After the first 70 pages the 1,111 affidavits to which we call attention as above immediately commence. Hence the exhibits above should appear at pages 71-3, but as the supplement is in fact paged, they are numbered pages 1, 2 and 3, immediately following page 70.

The aforesaid witness, Frank Shippen, in September, 1906, made an affidavit, reciting:

> "The settling of this mist or vapor is not a thing which occasionally occurs during the year, but has within the past two or three years been a matter of repeated occurrence. This vapor has been generally noticed by citizens and residents and has caused extensive comment.
>
> "Particularly has this been the case during the spring and summer of this year, while heretofore, to-wit: prior to May, 1906, these fumes were rarely ever noticed in deponent's neighborhood except late at night and early in the morning," etc. (Ib., p. 35).

Aside from the statements of the 1,111 deponents for Plaintiff showing that the damage began in the spring of 1906 with the blowing in of the Tennessee Copper Company's tall stack, all of which are found in the Supplemental Evidence and Exhibits filed by Plaintiff at the October Term, 1906, the following are a few extracts from the many affidavits therein appearing directly attributing the injury complained of to the installation of the high stack:

> "The erection of the high stack by the defendant Tennessee Copper Company has increased the carrying power of said fumes, and while it has, to some

extent, relieved the situation in and around the immediate vicinity of said furnaces, it has very much aggravated the condition of things for many miles further away, which has produced great damage to timber and destruction of crops in territory not heretofore injuriously affected." (Ib., p. 174).

"Greater damage has been wrought to farming lands, timber, orchards, crops and gardens during the past spring and summer (1906) than ever accomplished in any three years previous—in fact, more damage per month was apparent for the months of June, July and August, 1906, than was noticeable per year prior to this time." (Ib., p. 204-5).

"Since the erection of the high stack this spring by the Tennessee Copper Company the destruction of all vegetation and crops, fruit, and farming, has been multiplied many times more than ever before." (Ib., p. 273).

"The erection of the high stack by the Tennessee Copper Company at McCay, Tennessee, has very greatly extended the territory formerly affected by smoke and fumes from defendants' furnaces." (Ib., p. 309).

"The erection of the high stack by the Tennessee Copper Company this year has greatly aggravated the situation. The smoke and fumes are present more often and in much greater volume and strength than ever before." (Ib., p. 315).

"The damage done to timber and vegetation in deponent's section of the county has been very greatly increased since the erection of the high stack by the Tennessee Copper Company." (Ib., 330).

"Since the erection of the high stack by the Tennessee Copper Company the territory heretofore in-

juriously affected by said fumes from said plant has been very greatly extended." (Ib., p. 345).

"The damage in deponent's community this year is two or three times greater than that done in the last two or three years previously. The erection of the high stack by the Tennessee Copper Company has only served to give the fumes greater carrying power." (Ib., 354).

At first it was supposed that the tall stack would remedy conditions. A stipulation to discontinue or postpone was filed for this reason. When conditions were not remedied, but materially aggravated, as result of the Tennessee Copper Company's tall stack, which it yet operates, plaintiff's application was renewed and the decision of 1907 was herein rendered. Shortly thereafter the Shippen's "arranged" with the Tennessee Company whereby for $50,00.00 paid to the Shippen Company, and $234,000.00 additional paid to the two Shippens for certain of their stock, that they, the Shippens, would aid the Tennessee Company to continue its operations which they, and others inspired by them, had complained of so bitterly. (See pages 109 to 121, inclusive, our brief).

The Shippens tried to bargain with the Ducktown Company, claiming "the Courts in Tennessee will not give anybody justice" (Vol. 1, p. 335). The Ducktown Company declined to engage them, or treat with them at any price. Thereupon the citizenship of North Georgia was again stirred up by them, and a subsequent legislative resolution passed whereby the Ducktown Company was to be proceeded against here—in default of its refusal to put up $25,000.00 for three years to be parceled out by a "commission" to the land owners in the territory embracing the Shippen lands. Its co-defendant of record here, its keen business competitor at all times, has since 1908 been the largest stockholder in the Shippen Brothers Lumber Company. Thus its competitor and its co-defendant of record is to share directly in all moneys the Ducktown Company

was asked to pay the Shippen Company, whether through the instrumentality of a "commission" or otherwise.

At the hearing last spring, counsel for plaintiff was interrogated by a member of this Court, as appears from stenographic transcript, and answered:

> "Mr. Justice Day: Can you distinguish the smoke from one of these institutions from that of the other?
>
> "General Felder: That is what we are trying to do.
>
> "The Court: Where you have a combined nuisance how are you going to hope for a separate final decree?
>
> "General Felder: If your Honor please, I have an authority I can give you where that particular matter has been passed upon with reference to these companies. It is a case reported in 113 Tenn., page 331."

We submit the question then put is apt, that it is not answered in the Tennessee case cited, and has not, and cannot be answered, in accordance with plaintiff's contention. Moreover, the licensing of the Tennessee Company and the recent revelations that plaintiff was really induced to act by the Shippens, constitute materially "changed conditions" as contemplated by the order permitting proof herein, such as warrant an absolute dismissal as to the Ducktown Company.

Respectfully submitted,

W. B. MILLER,

J. A. FOWLER,

Solicitors for Ducktown Sulphur, Copper & Iron Company, Limited.

NO. 1, ORIGINAL

FILED
MAY 20 1915
JAMES D. MAHER
CLERK

In the Supreme Court of the United States

OCTOBER TERM, 1914.

THE STATE OF GEORGIA, PLAINTIFF,

vs.

THE TENNESSEE COPPER COMPANY

and

THE DUCKTOWN SULPHUR, COPPER AND IRON COMPANY, LIMITED, DEFENDANTS.

IN EQUITY.

SUGGESTIONS AND FORM OF DECREE SUBMITTED BY DEFENDANT DUCKTOWN SULPHUR, COPPER & IRON COMPANY.

W. B. MILLER,
J. A. FOWLER,
Solicitors for Defendant
Ducktown S. C. & I. Co.

To the Honorable The Supreme Court of the United States:

Availing itself of the suggestion of the Court in the opinion handed down on Monday, May 10th, in the case of State of Georgia against Tennessee Copper Company and Ducktown Sulphur, Copper & Iron Company, that either side may within ten days present a decree in conformity with the opinion together with such suggestions as seem desirable, defendant Ducktown Sulphur, Copper & Iron Company submits herewith a form of decree which it believes conforms to the requirements expressed in the opinion, and also submits the following suggestions:

1st. The requirement, that it shall not permit to escape into the air during any one day from April 10th to October 1st of each year gases the total sulphur content of which shall exceed twenty tons during any one day, may prove onerous, as the sulphur content of the ore varies from day to day, and the percentage of the sulphur cannot be anticipated, and hence in order to make certain that the specified amount be never exceeded the operation of the plant will have to be so conducted that generally the tonnage of sulphur will be very much below the amount stated. This will necessitate the reduction to some extent of the output of copper and the consequent curtailment of the force of employees. The designation of a certain quantity of sulphur as a maximum amount which defendant may at *any time* emit would very much hamper, if not prevent, any extensive enlargement of the plant. But as this decree is apparently designed as a temporary one subject to modification on the incoming of the Inspector's report, or on application of either party supported by proof, the effect of this provision will probably not prove so serious. Defendant suggests, however, that as an expert appointed by the Court will be at frequent intervals upon the ground,

this provision be modified by adding thereto the following:

"But the said Inspector may, after careful observations and investigation increase this maximum to such an amount as in his judgment defendant may permit to escape, and yet do no material damage to the forests and crops in the State of Georgia."

2nd. With reference to who shall be appointed as Inspector, defendant only suggests that he combine practical with theoretical knowledge and skill in metallurgy and chemistry, and possess practical experience in the operation of a plant of this or of a kindred character; and if consistent that he also possess expert knowledge as to the effect of sulphur dioxide upon forests and crops; and especially that he be imbued with a spirit of fairness and have no interest or feeling in the matters involved. Naturally it would be supposed that one possessing at least a part of these qualifications would as likely be found in the employment of the United States Government as elsewhere; but the fact that the Government has purchased lands in the vicinity of the plant, and that the Department of Agriculture has taken sufficient interest in behalf of the State of Georgia to send its own employees to testify in its behalf, is suggested for consideration in determining whether an expert so employed, if otherwise fully competent, would feel no interest in the matters in controversy.

Very Respectfully,

W. B. MILLER,
J. A. FOWLER,
Sols. for Deft.
D. S. C. & I. Co.

STATE OF GEORGIA
Versus
TENNESSEE COPPER COMPANY AND DUCKTOWN SULPHUR, COPPER AND IRON CAMPANY, LIMITED.

No. 1—ORIGINAL

This cause came on to be heard upon plaintiff's motion for a final decree against the Ducktown Sulphur, Copper & Iron Company, Limited, and argument of counsel being heard and due consideration given to the evidence on file, and it appearing that the Court hath heretofore adjudged that defendant was permitting smoke to escape from its plant and pass into the territory of the plaintiff in such quantities and of such character as to cause material damage to the forests and crops therein, and that therefore the burden is upon defendant to show that the condition of its plant and the method of operating the same are now such that material damage is no longer produced to the forests and crops in the State of Georgia by its operation; and it further appearing that defendant has not fully disclosed the nature and extent of the improvements upon its plant and the method of its operation and the results accomplished thereby, and has failed to show that no material damage results to the forests and crops in the State of Georgia from the escape of poisonous fumes therefrom, and the Court being of the opinion that plaintiff will obtain adequate relief if said plant be operated under the following conditions and restrictions:

It is therefore ordered, adjudged and decreed:

(1) That said defendant keep daily records showing fully and in detail the course and result of the operations of its plant.

(2) That ..... be and is hereby appointed as an inspector to observe the operations of said plant, and said defendant shall give said

..... at all times free and full access to all of its books, records and premises, and

said ..... shall during the next six months after the date of this decree make frequent and careful observations at least once each fortnight of the conditions of said plant, of the manner of its operation and of the quantity and character of smoke emitted therefrom, and at the end of that period of time he shall make a full report of the result of his observations, accompanied with full recommendations as to what future action will be appropriate; and to cover reasonable com-

pensation for the services of said ..... and the necessary costs and expenses incident to said inspection, defendant is required to deposit with the Clerk of this Court within the next ten days the sum of

$..... .

(3) That said defendant shall not permit the escape into the air of fumes carrying more than forty-five per cent of the sulphur contained in the green ore subjected to smelting. And

(4) That said defendant shall not permit to escape into the air gases the total sulphur content of which shall exceed twenty tons during one day from April 10th to October 1st of each year, or to exceed forty tons during one day in any other season of each year.

This cause is retained upon the docket of the Court for further action, and either party may at any time hereafter apply to the Court for appropriate relief.

MAY 17 1915
JAMES D. MAHER
CLERK

Supreme Court of the United States

October Term 1914

No. 1.—Original

IN EQUITY

THE STATE OF GEORGIA, *Complainant*

vs.

THE TENNESSEE COPPER COMPANY AND THE DUCKTOWN SULPHUR, COPPER AND IRON COMPANY, Limited, *Defendants.*

FORM OF INJUNCTIVE DECREE AGAINST THE DUCKTOWN SULPHUR, COPPER AND IRON COMPANY.

WARREN GRICE,
Complainants Attorney.

Supreme Court of the United States

October Term 1914

No. 1.—Original

The State of Georgia,
Complainant,

vs.

The Tennessee Copper Company and The Ducktown Sulphur, Copper and Iron Company, Limited,
Defendants.

In Equity.

Comes now the Complainant under leave granted by the Court on May 10, 1915, and presents a form of decree to be entered in conformity with the opinion of the Court in said cause.

Respectfully submitted,

WARREN GRICE,

Counsel for Complainant.

Supreme Court of the United States

October Term 1914

No. 1.—Original

The State of Georgia,
Complainant,

vs.

The Tennessee Copper Company and The Ducktown Sulphur, Copper and Iron Company, Limited,
Defendants.

In Equity.

The complainant having moved the Court to enter an injunctive decree against the Ducktown Sulphur, Copper and Iron Company, Limited, in conformity with the decrees of the Court heretofore entered, and the opinion of the Court in the cause; and it now appearing from the proofs submitted that the said defendant, The Ducktown Sulphur, Copper and Iron Company, Limited, its officers, servants, agents and employees under its control are guilty of the acts complained of in the smelting of its copper ore, and that its plant as conducted is injuring and damaging complainant and its citizens by discharging poisonous, noxious, and unwholesome fumes and gases which are carried by the air currents over the territory of the State of Georgia:

It is now here ordered, adjudged and decreed that said defendant, The Ducktown Sulphur, Copper and Iron Company, Limited, its officers, servants, agents and employees are hereby perpetually restrained and enjoined from so using, managing, maintaining, or in any manner operating any furnace, pit, oven, or other appliance or copper reducing method which causes,

generates, gives off or discharges any poisonous, noxious, or unwholesome gas, vapor, or fume, otherwise than upon the terms and conditions following:

(1) It shall keep daily records showing fully and in detail the course and result of the operations.

(2) A competent inspector to be appointed by this court shall have access to all the books and records of the Company, shall make frequent careful observations of the conditions—at least each fortnight—during the next six months, and at the end of that time shall make full report with appropriate recommendations. An adequate sum to cover the necessary costs and expenses must be deposited with the Clerk by the Company, which said sum is hereby fixed for the present at ten thousand dollars.

(3) It shall not permit the escapement into the air of fumes carrying more than 45 per cent of the sulphur contained in the green ore subjected to smelting.

(4) It shall not permit escaping into the air of gases the total sulphur contents of which shall exceed 20 tons during one day from April 10th to October 1st of each year, or exceed 40 tons in one day during any other season.

(5) The Court hereby appoints as the inspector above referred to Charles Lathrop Parsons.

The cause is hereby retained for further action and either party may apply hereafter for appropriate relief.

It is further ordered, adjudged and decreed that the said complainant do recover of the defendant, The Ducktown Sulphur, Copper and Iron Company, Limited, its costs in this suit to be taxed.

FILE COPY.

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JAMES D. MAHER
CLERK

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REPORT

TO THE

Supreme Court of the United States

IN THE CAUSE

No. 1 ORIGINAL—OCTOBER TERM, 1914

The State of Georgia,
Complainant,

vs.

The Tennessee Copper Company and the Ducktown Sulphur, Copper & Iron Company, Limited.

On Motion to enter a final decree against the Ducktown Sulphur, Copper & Iron Company, Limited.

By JOHN T. McGILL, Inspector
NASHVILLE, TENNESSEE

January 1, 1916

BRANDON-NASHVILLE

REPORT

TO THE

Supreme Court of the United States

IN THE CAUSE

No. 1 Original—October Term, 1914

The State of Georgia,
Complainant,

vs.

The Tennessee Copper Company and the Ducktown Sulphur, Copper & Iron Company, Limited.

On Motion to enter a final decree against the Ducktown Sulphur, Copper & Iron Company, Limited.

By JOHN T. McGILL, Inspector
Nashville, Tennessee
January 1, 1916

To the Honorable Supreme Court of the United States:

In obedience to a decree in this cause, I beg leave to submit the following report:

DECREE

On consideration of the motion of complainant for final injunction, the application of defendant Ducktown Sulphur, Copper & Iron Company, Limited, to show changed conditions, the proof submitted thereon, and of the argument of counsel thereupon had, and the Court being of opinion that by reducing the amount of sulphur discharged into the air said defendant probably can operate its plant without subjecting the territory of Georgia to serious danger of immediate injury, and deeming it desirable to be more fully informed concerning the true conditions and results which may be obtained by subduing the noxious gases discharged,

IT IS ACCORDINGLY ordered, adjudged and decreed:

(1) That the defendant Ducktown Sulphur, Copper & Iron Company, Limited, shall hereafter keep daily records showing fully and in detail the course and result of its operations.

(2) That Dr. John T. McGill, of Vanderbilt University, Nashville, Tennessee, is hereby appointed inspector to observe the operations of said defendant's plant and works. He shall be given by it at all times free and full access to its books, records and premises, and during the next six months he shall make frequent and careful observations—at least once each fortnight—of the conditions of the plant and works, the manner of their operation, the quantity and character of smoke emitted therefrom, and the resulting effect upon vege-

tation within the vicinity and in the State of Georgia. At the end of that time he shall make a full report of his observations accompanied by recommendations as to appropriate future action. To cover necessary cost and expenses incident to these services and the reasonable compensation of the Inspector, the defendant Ducktown Sulphur, Copper & Iron Company, Limited, is hereby directed to deposit with the Clerk of this Court, within ten days, the sum of five thousand dollars. Of this sum not exceeding two thousand dollars shall be paid from time to time, prior to October 12th next, by the Clerk to the Inspector, upon his written application, to cover costs, expenses, and on account of his services, etc.

(3) That said defendant hereafter shall not permit the escape into the air from its works of fumes carrying more than 45% of the sulphur contained in the green ore subjected to smelting.

(4) That it shall not hereafter permit to escape into the air of gases the total sulphur content on which shall exceed twenty tons during one day from April 10th to October 1st of each year or exceed forty tons in one day during any other season.

(5) That the cause will be retained upon the docket for such further action as may appear proper and either party may at any time hereafter apply for relief as it may be advised.

June 1, 1915.

(Signed) JAMES D. MAHER,
Clerk Supereme Court, U. S.

Scope of the Investigation

According to the decree the Court desires to be more fully informed concerning the true conditions and the results which may be obtained by subduing the noxious gases discharged; and the inspector is asked to report:

(1) The conditions of the plant and works.

(2) The manner of their operation.

(3) The quantity and character of the smoke emitted therefrom.

(4) The effect of the smoke upon vegetation within the vicinity and in the State of Georgia.

(5) Recommendations as to appropriate future action.

While it may be assumed that the report should include information or statements respecting each and every one of these specified subjects, it is not supposed that they are all considered of equal importance. For example, full and detailed information about the conditions of the plant and works would encumber the report with matter not germane to the questions at issue in the case; whereas the determination of the amount of sulphur in the escaping gases is of great importance, and it may be necessary to put on record numerous observations and state details in matters of procedure in order to inspire confidence in the results. But, as opinions will differ as to the relative importance of the various kinds of observations called for in the decree, it seems wiser to put into the report information that might be regarded as immaterial rather than risk omitting what might be considered essential.

The Plant and Works

The Company's plant and works consists of mines in Polk County, Tennessee, containing sulphur, copper and iron ores, and of the copper smelter at Isabella, Tennessee, with its accessories, the sulphuric acid plant and the reduction plant.

The Mines

There are three mines now open, the Mary mine, the East Tennessee mine, and the Isabella mine. The ores mined are essentially varying mixtures of pyrrhotite $Fe_7 S_8$ and chalcopyrite Cu Fe S_2. The number of tons of ore taken from these mines during 1914 and the first six months of 1915 and the percentage composition of the different ores are shown in table 1.

TABLE 1

1914

(First six months.)

	Ore	*Copper*	*Iron*	*Sulphur*
Mary mine	86255.1	2.19	28.27	19.33
East Tennessee mine	308.1	3.52	16.20	12.15
Isabella mine	1675.1	0.86	49.79	31.66

(Second six months.)

Mary mine	68888.9	2.32	32.86	21.46
East Tennessee mine	6504.6	2.79	15.22	10.62
Isabella mine	647.3	0.89	48.19	32.63

1915

(First six months)

Mary mine	75316.2	....	.....	20.62
East Tennessee mine	9704.8	....	.....	11.52
Isabella mine	828.4	....	.....	31.84

The Smelter

The capacity of the smelter is from 600 to 700 tons of ore per day of twenty-four hours, with an output of 16,000 pounds of high grade matte assaying from 40 to 47% of copper. While operating under the decree of the Court, limiting the sulphur content of the escaping gases to not more than 20 tons per day, the charge of ore has been from 300 to 400 tons per day with an output of from 13,000 to 14,000 pounds of high grade matte.

There are two furnaces, No. 1 and No. 2, whose dimensions are length 32 feet, depth 11 feet, diameter at top 6 feet, at bottom 5 feet, with movable forehearth about 3 feet long, 3 feet wide and 2 feet deep. The lid, which can be raised by compressed air, fits into a groove in the rim of the furnace, and is attached to a truck which runs on a track lengthwise of the furnace. The lid and the bottom and walls of the furnace are jacketed, so that the furnace may be cooled by water on all sides. One hundred thousand gallons of water per hour run through the cooling jackets.

The Sulphuric Acid Plant

The sulphuric acid plant covers an area of two and one-third acres. Its capacity is as much as 160 tons per day of 60 degrees Baumé acid (77.67%); but the average production is about 135 tons under the usual conditions. From three to six tons of this acid is not shipped, but is used in the niter pots to form the nitrous fumes required in the chamber process of making sulphuric acid. From 5,000 to 7,000 pounds of sodium nitrate are used daily.

Its construction is that of a modern plant, modified

to adapt it to the manufacture of sulphuric acid by the chamber process from the gases emitted from a blast furnace in which sulphide ores are smelted. The dust chamber and flue system connecting it with the furnaces is more extensive than in the ordinary plant.

There are two large buildings,—one for the Glover and Gay Lussac towers, the other for the acid chamber. Connecting these is the fan room, which contains besides the fans circulation tanks and acid eggs. To the east of these buildings are the storage tanks and the acid concentration building. The niter house and flue room adjoin the tower house on the north side. There is room in the tower house for additional Glover and Gay Lussac towers. The concrete foundation and the steel framework are already in place for three more Glovers and four more Gay Lussacs.

The Reduction Plant

The reduction plant consists of the bag house, figure 1, the furnace and condenser house, and the condensing chamber. Flues connect the bag house with the dust chamber and with the furnace, and a fan between the bag house and furnace gives the necessary draft.

The object of the reduction plant is to make elemental sulphur out of the sulphur dioxide of the smelter smoke.

There are many other subsidiary parts of the work,—the power house, blower house, machine shops, etc.—which need not be described.

The *conditions* at the smelter in so far as they relate to the investigation are developed under the discussion of the manner of operation and elsewhere in this report.

The Operation of the Plant and Works

Two branches of work are embraced in the company's operations,—the mining of the ores and the smelting of the ores, in each of which, under normal conditions, from two hundred to three hundred men are employed.

The Course of the Ore from Mine to Matte

The ore at the Mary and East Tennessee mines is taken at deep levels to shafts, raised to the surface by steam hoists, and conveyed to the bunkers of the smelter on the company's railway. The Isabella mine is near the smelter, and the ore is mined not much below the level of the smelter yard.

The ore of the East Tennessee mine contains the highest percentage of copper, that of the Isabella mine the lowest. The ore of the Isabella mine contains the highest percentage of iron, and that of the East Tennessee mine the lowest. On days when high grade matte is made, it is the custom to put into the charge a larger proportion of East Tennessee ore than on other days. Isabella ore is used at times to increase the proportion of iron in the slag, but it has of course also the effect of increasing the proportion of sulphur in the escaping gases.

The ores are delivered from the bunkers into the charging car and weighed on Fairbanks scales. Weighed amounts of silica and coke are added in such proportions as are required to form an easily fusible slag. The normal charge is about 7,000 pounds of ore mixed with from five to seven per cent of its weight of coke and a variable amount of silica.

The charge rests in the car on a horizontal belt which may be made to revolve over rollers at the rear and

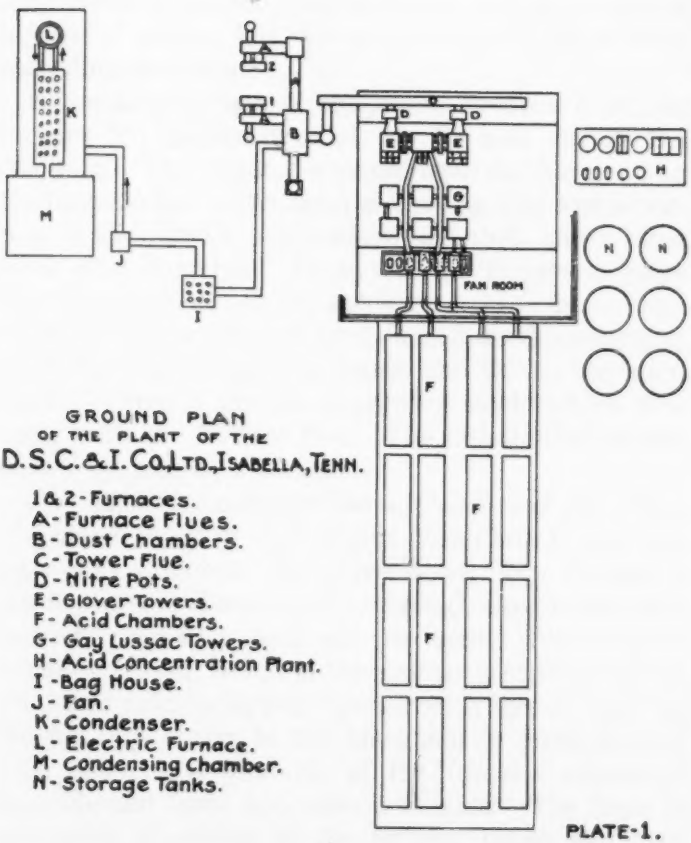
near the front of the car with a motion independent of that of the car. As the car traverses the length of the furnace, pushing or pulling the truck carrying the raised furnace lid, the charge is dropped at the end of the belt near the front of the car and distributed at the will of the smelter.

Only one furnace is operated at a time except for a short period when a change is made from one furnace to the other. The blast of about 80,000 cubic feet per ton of ore smelted enters the furnace through fifty-six tuyers, 3 inches in diameter, at atmospheric temperature, and a pressure of 20 to 30 ounces.

The Furnace Products and their Flow

The furnace products are the *matte*, the *slag*, and the *smoke* mixed with the residual air of the blast. The slag floating on the matte runs in a continuous stream from the forehearth. As it falls, a powerful current of water, issuing under pressure from pipes, strikes and granulates it. Two thousand gallons of water per ton are used. The granulated slag is raised by an endless chain of buckets and thrown into a bin, from which it is run into cars and dumped. A small portion of the slag takes the course of the low grade matte. The low grade matte, containing from 12 to 20% of copper and from 22 to 24.5% of sulphur, is withdrawn at intervals into ladles and poured out into open ground beds, where it solidifies on cooling. It is broken up, and about once a week it is smelted again in the furnace to produce high grade matte, which is cast into pigs and shipped. The high grade matte contains from 40 to 47% of copper and about 23.5% of sulphur.

The *smoke* contains three different kinds of material,



GROUND PLAN
OF THE PLANT OF THE
D.S.C.&I.Co.LTD.,ISABELLA,TENN.

1&2-Furnaces.
A-Furnace Flues.
B-Dust Chambers.
C-Tower Flue.
D-Nitre Pots.
E-Glover Towers.
F-Acid Chambers.
G-Gay Lussac Towers.
H-Acid Concentration Plant.
I-Bag House.
J-Fan.
K-Condenser.
L-Electric Furnace.
M-Condensing Chamber.
N-Storage Tanks.

PLATE-1.

—the flue dust, the fume, and the gas. The flue dust consists of solid particles of the charge thrown out of the furnace by the force of the blast. The fume consists of the vapors of substances formed in the combustion, which at ordinary temperatures are condensed to liquids or solids, but under certain conditions with exceeding slowness.

A variable portion of the smoke escapes from the furnace by leakage around the lid and during the charging. The remainder passes from the furnace into the furnace flue, where most of the flue dust and a portion of the fume are deposited, and then into a large brick dust chamber. From this the fume and gases are distributed (1) to the sulphuric acid plant by way of the circular tower and long flue, (2) to the reduction plant by way of the bag house, and (3) to the main stack. There is also an emergency stack, which connects with the furnace flue. The distribution is regulated by means of dampers.

(1) *The gases that enter the sulphuric acid plant* take the course usual in such plants, (See Plate 1) over the niter pots (D), into the Glover tower (E), through a fan to the acid chambers (F), through a fan to the Gay Lussac tower (G), and out the vent. The sulphur dioxide in them, which in the process is converted into sulphuric acid, is largely diluted with the nitrogen of the air that enters in the blast and is contaminated with deleterious products of the furnace, especially uncondensed fume and carbon dioxide. The fume is deposited as sludge in the settling tanks and acid chambers. The deleterious effects of carbon dioxide are obviated or counteracted by methods devised and precautions exercised by the manufacturers. The average composition of the gas before it enters the plant,

distinct from the fumes, is reported by the company to be sulphur dioxide 3 to 8%, carbon dioxide 3 to 11%, oxygen 0.5 to 11%, nitrogen in large quantities.

(2) *The smoke that leaves the dust chamber for the reduction plant* must be freed from fumes before the sulphur dioxide in it can be reduced to sulphur of high grade. This is accomplished in the bag house, where it passes into long woolen bags suspended from wires running across horizontally near the top of the house. The fume is retained in the bags by the meshes and is shaken out at intervals.

The gases are drawn by a fan from the bag house (See Plate 1) through a flue and passed into the condenser and furnace house, where they are conducted through a series of tubes in a large brick condenser, then into the furnace, up through the coke, heated to incandescence by an electric current. The reduction may be represented by the following reactions: $SO_2 + C = CO_2 + S$, $SO_2 + 2CO = 2CO_2 + S$. The vaporized sulphur passes from the furnace into the brick condenser mentioned above, pre-heating the gases passing through the tubes on their way to the furnace, and finally to the large condensing chamber.

The Quantity of Smoke Emitted from the Plant and Works

The quantity of smoke emitted from the plant and works is asked for in the decree of the court. The quantity of smoke could be determined readily if all the smoke came out through the stack and with some degree of regularity. This is not the case. A considerable amount of smoke escapes from the furnace

whenever it is charged,—and this happens more than a hundred times a day— and at the top around the lid there is a constant leakage which it is impossible to measure. The smoke from the stack varies greatly at different times of the day, the damper being raised or lowered to regulate the amount needed for the sulphuric acid factory. For these and other reasons no attempt was made to *measure the quantity of smoke* emitted from the works.

The volume of the blast being known, the quantity of gases coming from the furnace can be calculated from the analysis of the material of the charge of the slag, no change of volume occurring in the oxidation of the coke to carbon dioxide and the sulphur of the ore to sulphur dioxide. But while this problem is of interest and value for metallurgical purposes, its importance in this investigation did not seem sufficiently great to warrant an attempt at its solution. The volume of the gases coming from the furnace may be taken as somewhat less but approximately the same as that of the incoming blast. It was decided, therefore, to *measure the volume of the air issuing from the blowers.* For this purpose the company kindly consented to put in an air flow meter. Delay in shipment prevented its instalment before Occtober. The result of its operation for twenty-three days shows an average flow of 27,300 feet per minute. The average flow on the 28th and 29th of October was 27,500 feet per minute. The green ore charge for those two days was 892 tons, and the total charge was 1,055 tons. This would give an average blast of 88,700 cubic feet per ton of green ore, or 76,000 cubic feet per ton of total charge. The number of observations however is too small for reliable results.

The Quantity of Sulphur Emitted from the Plant and Works

The quantity of smoke emitted is not of so much importance in this investigation as the quantity of *injurious gases,* particularly sulphur dioxide, in this smoke. A knowledge of the quantity of smoke would of course enable one to determine the quantity of sulphur dioxide by analysis. But as the quantity of smoke could not be determined accurately, another method was adopted to determine the quantity of sulphur dioxide. For convenience the statements are made in terms of sulphur, which is one-half by weight of the sulphur dioxide.

The amount of sulphur escaping into the air is taken as the difference between the amount of sulphur in the material put into the furnace and the amount in the matte, slag, flue dust, and acid recovered.

Daily Record; Furnace Charge Calculation

A daily record of these items, under the title "Furnace Charge Calculation," has been kept by the company since May 1, 1915, the day of this appointment, up to December 1. Sample copies of these daily reports are shown in Table 2.

The correctness of the conclusions as to the quantities of sulphur emitted depends upon the accuracy of those reports with respect to the items under the headings "material treated, lbs.," and "sulphur." Therefore, we have given these items careful attention.

The mines were visited and the sampling and weighing of the ores observed. The measurement and method of estimating the amount of acid made per day were

examined. Individual reports to the office for certain days were called for and the summation of the items verified. Daily duplicate samples of ore, matte, and slag were taken, and a number of samples of the sulphuric acid. Certain of these were sent away to chemists to check the analysis made in the company's laboratory and to determine whether the results obtained otherwise, as explained below, were correct.

TABLE 2

FURNACE CHARGE CALCULATION

June 6, 1915.

	Material Treated	*Copper*		*Iron*		*Sulphur*	
	Lbs.	*%*	*Lbs.*	*%*	*Lbs.*	*%*	*Lbs.*
Mary mine ore...	595,287	2.37	14,108	31.40	186,920	19.28	114,771
E. Tenn. ore.....	195,228	3.72	7,262	14.55	28,405	10.08	19,679
Matte.....	27,160	15.94	4,329	49.00	13,308	24.55	6,668
Briquettes.....	13,500	2.22	300	21.31	2,877	12.85	1,735
Coke.....	50,400	.....	.....	.....	.....	.....	.....
Totals.....	881,575	.....	25,999	.....	231,510	.....	142,853
Matte.....	149,050	15.94	23,725	49.00	73,025	24.55	36,600
Slag.....	540,200	.24	1,296	27.60	149,092	2.45	13,505
Flue dust.....	44,079	2.22	978	21.31	9,393	12.85	5,664
Acid.....	278,000	.....	.....	.....	.....	25.40	70,612
Balance.....	.....	.....	.....	.....	.....	.....	16,472
Totals.....	.....	.....	25,999	.....	231,510	.....	142,853

FURNACE CHARGE CALCULATION

September 11, 1915.

Mary mine ore...	689,040	2.36	16,261	33.20	228,761	20.27	139,668
E. Tenn. ore.....	114,840	6.45	7,407	22.70	26,068	16.27	18,684
Matte.....	34,650	11.82	4,095	51.75	17,931	24.75	8,576
Quartz.....	1,800	.....	.....	.....	.....	.....	.....
Coke.....	43,050	.....	.....	.....	.....	.....	.....
Totals.....	883,380	.....	27,763	.....	272,760	.....	166,928
Matte.....	211,750	11.82	25,029	51.75	109,520	24.75	52,410
Slag.....	529,500	.22	1,165	28.00	148,180	1.85	9,795
Flue dust.....	70,670	2.22	1,569	21.31	15,060	12.85	9,081
Acid.....	266,000	.....	.....	.....	.....	2.54	67,564
Balance.....	.....	.....	27,763	.....	272,760	.....	28,078

The company employs three chemists who make determination daily by analysis of copper, iron, silica, sulphur in ores, copper in matte, copper, iron and silica in slags. The iron and sulphur in matte are estimated in conformity with metallurgical practice elsewhere, from a diagram showing by means of curves the relation of the sulphur and iron to the copper in the matte. The flue dust is taken as 8% of the total charge and its content of sulphur established by a semi-annual analysis of a composite sample.

As the percentage of sulphur in slag is small, and its variation is of no practical consequence in the smelting of copper ores, it is determined like that of flue dust, by a semi-annual analysis. But in ascertaining the amount of sulphur in the escaping gases by the method now under consideration, this percentage becomes a factor of some importance on account of the great weight of slag. From June 1, 1915, to August 31, 1915, the percentage was taken as 2.45 in making up the daily record. A change was then made to 1.85 as the result of an analysis made by the company at the suggestion of the inspector. The company's records show that percentages ranging from 1.32 to 2.08 have been used during the last ten years. Analyses of six samples of slag, two of which were duplicates, made by the N. B. Pratt Company, of Atlanta, and W. E. Grainger, of Knoxville, give sulphur ranging from 0.96% to 1.42% with an average of 1.24%. Taking the daily average amount of slag as 300 tons, the company's estimate of sulphur escaping daily in the gases seems to be too low by 3.6 tons from June 1st to August 30th and 1.8 tons after August 30th. The company should however be allowed a credit of about six-tenths of a ton per day for sulphur lost in the sludge of the acid plant. This would

reduce the above figures to 3 tons and 1.2 tons respectively.

Analyses of the other materials gave figures in close accord with those used by the company in making up the record, including those for sulphur in the matte estimated by means of the curve.

The attention of the manager of the company was called to the fact that on some days the quantity of sulphur escaping in the gases exceeded the limit prescribed by the Court, and that this should be corrected or explained. The explanation was presented in a paper which it seems fair to the company to include in the inspector's report. (See Exhibit A, p. 61.)

Comments on the Company's Statement

The diagram gives a summation of three items of the daily furnace charge record for six months. A slight variation from the record may be noted in the sulphuric acid line, due to the fact that, instead of the total quantity formed, the net daily production was taken after deducting the three to six tons used in the niter box. This does not affect the line showing the quantity of escaping sulphur, as in getting the data for this the total daily production of acid was taken.

It seems evident that the company was not able to regulate accurately the amount of escaping sulphur, else it would have operated to its own advantage on a larger scale with an escape of between nineteen and twenty tons of sulphur instead of sixteen or seventeen tons, and without making itself liable to the charge of infringement of the Court's order.

The adjustments for successful operation are difficult, especially on a small scale with limitation as to the

amount of escaping sulphur. If the metallurgist uses ores rich in sulphur, more sulphur escapes; if poor in sulphur more coke must be added for fuel, thus forming more carbon dioxide, which retards the formation of sulphuric acid. On the small scale, the fuel, either sulphur or coke, must be proportionately greater, because the loss of heat from the furnace by radiation is not much less for the small charge than for the large. If the blast is increased in order to maintain the intensity of the heat, the gases that go to the acid plant are not so efficient for acid making because of increased dilution of the sulphur dioxide. If the heat is not sufficiently high, the contents of the furnace freeze. This happened twice during the summer.

The Ducktown Company and the Tennessee Company are the only ones known that make sulphuric acid as a by-product from the residual gases of a blast furnace copper smelter. The difficulties in manufacture have been overcome to such an extent as to make the process successful commercially where a market for the acid is near at hand, but the working of the Isabella plant is far from uniform. Only twice during the six months here considered has the full capacity of 160 tons per day been realized. The average number of tons of acid per day has been for June 108.4, July 129.6, August 110.5, September 113, October 127.4, November 113.5, giving an average per day for the six months of 118.4 tons.

The following summary, quantities reckoned in tons, has been made from the daily record from June 1, 1915, to December 1, 1915.

TABLE 3

Months	*Green ore smelted*	*Sulphur in green ore*	*Acid made*	*Sulphur in acid*	*Per cent of sulphur Recov'd*	*Sulphur escaping*	*Per cent of sulphur Escap'g*
June	9164.3	1598.3	3487.0	885.7	55.42	441.0	27.59
July	9910.1	1869.0	4018.1	1020.6	54.55	456.1	24.40
August	9444.3	1672.8	3421.3	869.7	57.99	508.4	30.39
September	10148.0	1898.6	3398.0	863.1	44.30	668.2	35.19
October	11732.4	2422.7	3949.3	1003.1	41.40	976.8	40.32
November	11308.2	2347.3	3405.5	875.4	37.29	1145.0	48.78
Per day 1st 4 mos.	316.93	67.94	117.41	29.82	51.70	17.00	29.46
Per day last 2 mos.	377.71	78.20	120.56	30.62	39.38	34.78	44.48
November only	376.94	78.24	113.52	29.18	37.29	38.17	48.78
Per day for 6 mos.	337.20	64.53	118.40	30.08	46.72	22.93	35.53

It appears from the above tabulated statement that reckoning the average amount of sulphur escaping per day in the gases for periods of one month, the limit of 20 tons was not exceeded in the first four months nor the limit of 40 tons in the last two months. If single days be considered, then the 20 ton limit was exceeded twenty-eight times in the 111 days from June 1st to September 20th, and the 40 ton limit six times in the 92 days it was allowable from September 20th to December 1st. The same explanations might be given of the transgressions in the latter period as have been offered for those of the former period.

Quantity of Sulphur Escaping Compared to that in the Green Ore

Let us now consider the quantity of escaping sulphur as shown in the above tabulated statement, with reference to that article of the Court's decree which reads, "That said defendant shall not hereafter permit the escape into the air from its works of fumes carrying more than 45% of the sulphur contained in the green ore subjected to smelting."

This is evidently not intended to apply to every single day, for on days when the furnace is run to make high grade matte the green ore constitutes but a small proportion of the charge, and the sulphur escaping, being derived largely from the low matte of the charge, may without exceeding the 20 or 40 ton limit in quantity be much above 45% of the green ore used in the smelting. Making the estimate by the month, it is found that the daily average for the first four months is 29.46%, for the whole six months 35.53%, for the last two months 44.48%, *for the month of November 48.78%*.

It may be said in behalf of the company that only on two days in November was the amount of escaping sulphur more than 40 tons, namely, November 10th, 47.96 tons, and November 21st, 40.12 tons. The daily record shows that the company was changing furnaces on November 10th. In doing this it is necessary to charge into the "blowing out" furnace a larger proportion of coke than usual. This increases the percentage of carbon dioxide in the furnace gases, which, retarding the formation of acid, allows more of the sulphur to escape into the air. The total amount of material charged into the furnaces that day was the largest of any day of the whole six months, yet the amount of sulphuric acid made was only 108 tons. The sulphuric acid plant seems to have not been working well in November. The average daily amount was 113.5 tons per day,—4.9 tons below the average of the other five months. Nevertheless, had the average in November been the same per day as during the other months, that is 119.43 tons, the percentage would have been 46.87%,—nearly 2% more than the limit.

The Character of the Smoke Emitted from the Plant and Works

The smoke issuing from the furnace contains, as has been stated elsewhere, flue dust, fume and gases.

Flue Dust and Fume

One may get an idea of the nature of the flue dust and fume from the following approximate analyses, the first four of which have been reduced to similar terms for the sake of comparison: No. 1 is flue dust from a green ore charge, No. 2 flue dust from a matte charge, No. 3 fume from the bag house, and No. 4 sludge (baked) from the acid chamber. No. 5 and No. 6 are the same analyses as No. 3 and No. 4, respectively, with the elements combined in the way the chemist considers most probable.

TABLE 4

	*1**	*2*	*3*	*4*	*5*	*6*
Water	.....	.....	.....	.....	15.84	16.14
Insoluble	.....	.....	.....	.....	0.54	1.45
Zinc total	6.61	4.53	33.00	28.60	.....	.....
Zinc Oxide	.....	.....	.....	.....	4.86	0.25
Zinc Sulphide	.....	.....	.....	.....	19.36	1.79
Zinc Sulphate	.....	.....	.....	.....	39.75	67.65
Sulphur (total)	12.82	10.88	18.98	15.64	.....	.....
Sulphur (free)	.....	.....	.....	.....	3.20	a trace
Sulphuric Acid	.....	.....	.....	.....	.....	0.70
Lead	.....	.....	7.45	a trace	.....	.....
Lead Sulphide	.....	.....	.....	.....	8.60	.....
Lead Sulphate	.....	.....	.....	.....	.....	a trace
Aluminum Oxide	4.58	3.87	1.23	0.77	0.71	0.36
Aluminum Sulphate	.....	.....	.....	.....	0.74	0.59
Iron Oxide	30.86	21.86	0.40	0.83	0.17	0.56
Iron Sulphate	.....	.....	.....	.....	0.49	0.63
Silica	29.55	25.23	.....	.....	.....	.....
Calcium Oxide	6.43	6.73	.....	.....	.....	.....
Magnesium Oxide	3.40	3.81	.....	.....	.....	.....
Copper	2.22	3.00	.....	.....	.....	.....

*Carbon undetermined

Comparing these, it may be seen that particles of the charge, such as silica, lime, iron, copper and carbon, are blown over in the blast and that the zinc and lead compounds especially are carried away in the fumes, getting into the bag house and the aicd chamber. The white fumes from the stack are probably much like the bag house precipitate in composition, consisting largely of oxides and sulphates of zinc and lead in a very finely divided state, partially or wholly enveloped in vapor of water and mixed with the gases of the smoke. The smoke from the top of the furnace contains flue dust, fume, and gases, and, when the charge is first put in, a small amount of elemental sulphur. The flue dust is soon deposited; while the fume and gases are, like those from the stack, carried away by the wind.

Nature of the Gases Escaping

In order to determine the composition of the gases escaping, analyses were made at seven different stations.

1. *The Furnace.* Samples were obtained by introducing a one-inch pipe horizontally through a hole in the side of the furnace near the top, the furnace being closed, and drawing the gases for analysis by aspiration through the absorption solutions of the apparatus. The results of analysis varied according to the time the sample was taken relative to the charging of the furnace.

Analyses made immediately after charging show a higher relative percentage of carbon dioxide and oxygen; those made some time after charging, a greater percentage of sulphur dioxide.

2. *The Furnace Flue.* The samples were taken near the entrance of the gases to the dust chamber. The results here are affected by irregularities in charging the furnace, the kind of charge, and the length of time after charging.

3. *The Dust Chamber.* The same factors as in the furnace flue affect the results, but not to the same extent.

4. *The Main Stack.* The samples were taken at a height of about 35 feet. The analyst attributes the higher percentage of oxygen and lower percentage of carbon monoxide and sulphur dioxide to the infiltration of air at the damper. The volume of smoke issuing from this stack at different periods of the twenty-four hours varies greatly on account of changes made in the position of the damper to meet the requirements of the sulphuric acid factory.

5. *The Emergency Stack.* The samples were taken at a height of about 30 feet. These analyses were made while this stack was used instead of the main stack after the "blowing in" of furnace No. 1 August 9th. The emergency stack is connected directly with the furnace flue.

6. *The Gay Lussac Tower.* The samples were taken from the exit stack a few feet above its junction with the tower.

7. *The Sulphuric Acid Concentration Plant.* The samples were taken from the exit stack of this plant.

8. *The Reduction Plant.* This plant was put in operation so late in the season that we were not able to get samples of the gaseous product for analysis. The company reports the presence of a large percentage of carbon dioxide, with only traces of sulphur dioxide.

For tabular statement of analyses and methods used see Exhibit B, p. 66.

In making up the report of analyses, no result has been included where there has been any reason to doubt its accuracy. Quite a number of analyses made and numbered consecutively are not given for various reasonable doubts as to correctness, but the original records of the analyses have been preserved.

The high temperatures registered in the analyses were taken with a Western Electric Company centigrade electric couple pyrometer. The taking of the temperature at the top of the furnace was overlooked at the time of getting the samples. One may get an idea of the temperature there at different periods from the following observations of September 14, 1915:

(1) Seven minutes after charging.....350 degrees C.
Nine minutes after charging.....225 degrees C.
Twelve minutes after charging.....675 degrees C.

(2) At time of charging.....675 degrees C.
Nine minutes after charging.....660 degrees C.
Twelve minutes after charging.....740 degrees C.

Certain irregularities in operation which might aid in accounting for variation in results are noted with the analyses.

The averages of the carbon dioxide and sulphur dioxide in six samples taken from the furnace, ten from the furnace flue, seventeen from the dust chamber, and four from the emergency stack are as follows:

Furnace.....Carbon dioxide, 8.50%; Sulphur dioxide, 4.40%
Furnace flue.....Carbon dioxide, 5.56%; Sulphur dioxide, 4.40%
Dust chamber.....Carbon dioxide, 6.56%; Sulphur dioxide, 6.10%
Emergency stack.....Carbon dioxide, 6.03%; Sulphur dioxide, 5.77%

Of these analyses, that of the sample from the dust

chamber probably most nearly represents the composition of the furnace gas with respect to these two constituents.

Sixteen analyses of the gas taken from the exit of the Gay Lussac tower gave an average of carbon dioxide 6.66%; sulphur dioxide, 0.27%; oxygen, 8.16%; and nitric oxide, 0.97%.

Inspecting these results, one may note with interest that the percentage of carbon dioxide is very nearly the same as was found in the dust chamber, that there is a considerable excess of oxygen—as might be expected from the abundant blast—that the sulphur dioxide has nearly all been eliminated from the furnace gas in making sulphuric acid, and that with the exception of two days there was no unusual loss of niter in the objectionable nitric oxide.

Not a sufficient number of analyses were made of the vapors given off at the concentration plant to warrant the drawing of inferences.

Effect of the Smoke Upon Vegetation Within the Vicinity and in the State of Georgia

The region here designated as within the vicinity and in the State of Georgia is practically conterminous with what, because of its characteristic topography, is generally known as the Ducktown Basin. A description of this basin with reference to the physical features that modify the diffusion of smoke and the relative position of important points seems appropriate here. Then may follow some account of how this condition was brought about and statements showing, first to what extent the Ducktown Company was responsible

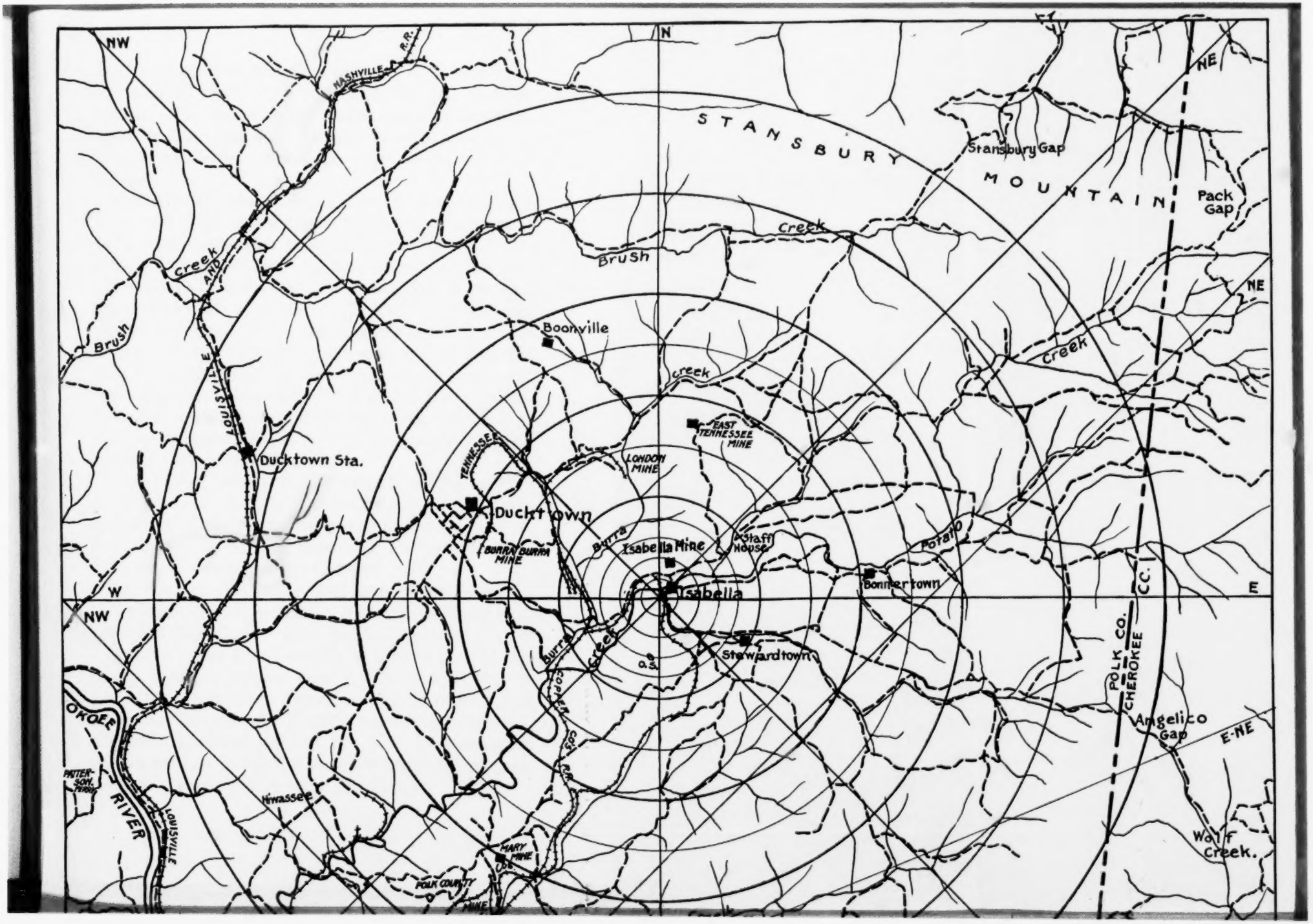
and, second what the Company claims to have done during the last eight years to abate the nuisance with which it was charged.

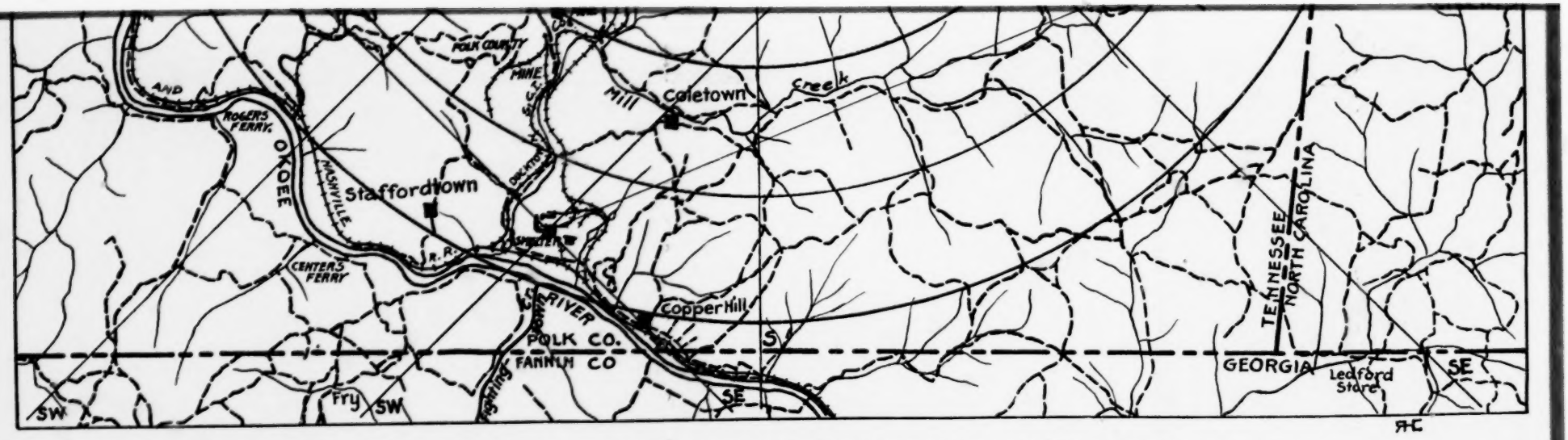
The Ducktown Basin

What is known as the Ducktown Basin includes a territory in Polk county, Tennessee, and Fannin county, Georgia, approximately an ellipse in shape, with major axis about sixteen miles long, running south 20 degrees west, and minor axis of half that length. The basin has an elevation of from 1,600 to 1,700 feet, is cut by streams into narrow valleys 100 to 150 feet lower, and bordered by a rim of ridges and mountains 300 to 1,500 feet higher. (See photographs.) About one-third of the basin lies in Tennessee, mostly north of the Ocoee river, or Toccoa, as it is called in Georgia, which, running in the general direction of west 30 degrees north, enters Tennessee at Copper Hill somewhat to the east of the major axis of the ellipse. Fighting Town Creek, a large stream emptying into the Ocoee opposite the plant of the Tennessee Company, which is in Tennessee at the mouth of Mill Creek one-half mile down the river from Copper Hill, drains the southern portion of the basin. The creeks coming into the river from the north, naming them from the west, are Brush Creek, Potato Creek, Mill Creek, and Wolf Creek. (See Plate 2.)

Condition of Vegetation in the Basin

A part of the Ducktown Basin north of the Ocoee river, estimated at some ten or twelve square miles, is devoid of vegetation with the exception of sage grass and wild smilax that have taken root here and there,


NW
N
NE
W
E
NW
NE
E-NE
NASHVILLE R.R.
STANSBURY MOUNTAIN
Stansbury Gap
Pack Gap
Brush Creek
Brush Creek AND
Boonville
Creek
Creek
LOUISVILLE
Ducktown Sta.
TENNESSEE
EAST TENNESSEE MINE
LONDON MINE
Ducktown
BURRA BURRA MINE
Burra Burra
Isabella Mine
Staff House
Potato
Isabella
Bonnertown
Stewardtown
Burra Burra Creek
COPPER
CREEK
O.S.
POLK CO.
CHEROKEE
CC.
Angelico Gap
Wolf Creek.
OKOEE
RIVER
PATTERSON, TENN.
LOUISVILLE
Nwassee
MARY MINE
O.S.
POLK COUNTY MINE



PART OF THE DUCKTOWN BASIN WITHIN THE VICINITY OF ISABELLA.

SCALE 1¾" = 1 MILE.

---- ROADS. RAILROADS STREAMS

PLATE 2

yards and gardens cultivated by a few of the residents, and several peach orchards; and the soil is badly eroded. The center of the barren region is somewhat south of the road from Isabella to Ducktown, not a great distance from where the roast sheds were once located.

Bordering this desert region is one covered with sage grass and vines and a few stunted shrubs and small trees, often with dead tops, that have survived. At some places numerous young maples are seen, but they are likely to be destroyed by fires starting in the sage grass in the fall or winter. Along the streams other grasses are found, and a more thrifty growth of trees on slopes and in hollows and coves somewhat sheltered from winds blowing from the central area. Dogwoods, sourwoods and blackgums constitute the principal growth in such places, and are especially noticeable in the late summer and in autumn because of the rich coloring their foliage assumes.

This almost treeless border extends on the east approximately to the North Carolina line, on the north to the top of the Stansbury mountain, on the west almost to the Little Frog mountain, and on the south from one to two miles into Georgia.

Out beyond this border the country for some distance is not heavily wooded. Most of the larger trees were cut down years ago, and sold to the Copper Company. The forest growth in a large part of this region does not appear thrifty. Trees with dead or dying tops seem more numerous than is usually seen under similar soil and climatic conditions elsewhere. Generally speaking, the area to which this description applies extends to the rim of the Ducktown Basin and perhaps even further in some directions.

Causes of Injury to Vegetation

The chief cause of injury to vegetation in the Ducktown Basin is generally admitted to be smoke emitted in the process of working the sulphureted ores of that region for copper. Before the organization of the Ducktown Company, the copper ores were smelted in charcoal reduction furnaces or worked by the leaching and precipitation process. Some of the timber was cut for making charcoal. The method used by the Ducktown Company for ten years after beginning operations in 1893 consisted in first roasting the ore in heaps between layers of wood in the open air and then smelting the roasted ore in a charcoal reduction furnace. The Pittsburgh Company adopted the same method in 1894, and this was continued by its successor, the Tennessee Copper Company. These roast sheds, as they were called, occupied acres of ground, and the wood required for firing them in the course of ten years practically exhausted the timber in the forest for miles around. The smoke from the burning wood and roasting ore formed a cloud so dense, old citizens say, that it was often difficult to find one's way through it. It must have gradually destroyed vegetation in the vicinity. Its area of destruction in the period of ten years was probably conterminous with the barren central zone described above. To complete the destroying work of the axe and the smoke, the rain is washing away the soil and leaving but furrowed hillsides almost beyond reclamation. (See photographs.)

Pyritic Smelting

About 1903 both companies began to prepare for smelting the green ore by the pyritic, or blast furnace,

process, and by the end of 1905 the open air roasting had ceased, and the latter process was in full operation. This eliminated the wood smoke and limited the escape of the smoke to the stack and the leakage from the furnace, but the amount of sulphur escaping into the air from the smelting of the ore in this manner was very slightly, if any, less than in treating the same amount of ore by roasting and charcoal smelting. The table below gives in the second column the number of tons of copper ore mined in Tennessee in the years annexed. The figures are taken from reports of the mining department of the State. The third column shows the number of tons of sulphur escaping into the air daily from the smelting of the ores, estimating the sulphur at 20% of the ore, for 1901, 1902, 1903, 1904 and at the recorded per cents of the Ducktown Company in the following years. The fourth and fifth columns are the same items as the second and third, but for the Ducktown Company alone.

TABLE 5

Years	*Tons of Ore*	*Tons of Sulphur escaping*	*Tons of Ore*	*Tons of Sulphur escaping*
1901	162,461	90.0	110,622	60.0
1902	335,864	184.0	127,613	70.0
1903	370,278	202.9	91,310	50.0
1904	384,886	216.9	138,524	75.9
1905	399,330	259.6	184,126	115.0
1906	538,141	303.5	189,506	147.0
1907	557,950	286.6	182,857	94.0
1908	618,806	303.0	167,183	70.0

Statistics for the Tennessee Copper Company are not at hand, but practically no copper ores were mined and smelted in Tennessee by any other than these two companies.

Complaint of Citizens and Injunction Proceedings

Comparing the figures for 1904, 1905, and 1906, it may be seen that soon after the change from the roasting to the pyritic method the scale of operation was largely increased, so that the quantity of gases or fumes escaping into the atmosphere was probably greater than ever before. Their sulphur content, estimated from the weight of the ore and the composition of the ore as used by the Ducktown Company, was above 250 tons a day. This condition incident to their operations was not satisfactory to the copper companies, for it subjected them to complaints of injury by citizens of the community in Tennessee and Georgia, and also it suffered a waste of material in the smoke, which should have been profitably utilized. Under like conditions in Europe, in several instances, high smoke stacks were erected with the purpose of saving vegetation from injury in the vicinity by preventing the smoke from reaching the surface of the earth, and at a distance by causing its dilution to such a degree as to render it harmless. In 1906 the Tennessee Company erected at Copper Hill a stack 325 feet high, that is about 175 feet higher than the general level of the higher ground in the Ducktown Basin. This, however, did not stop the complaint of the citizens. It was taken up by others farther away, until the State of Georgia, in behalf of its citizens, entered suit against both of the Companies and, May 13, 1907, the Supreme Court of the United States decreed that the State of Georgia in her sovereign capacity had the right of permanent injunction if she insisted upon her extreme rights. The State of Georgia, however, did not then insist

upon a final decree, but postponed action in order to allow defendants time to install certain appliances and apparatus which it was claimed by the defendants would eliminate the gases and fumes complained of from the atmosphere, thereby abating the nuisance.

In 1913 the State of Georgia entered into a stipulation with the Tennessee Company, granting a continuance of three years, but, failing to come to a similar agreement with the Ducktown Company, filed a motion for final injunction against this Company. The Ducktown Company claims that conditions have improved since 1907 and that no damage is now done to vegetation in Georgia by fumes or gases emitted in the operation of its plant. The Court has deferred final decision pending the ascertainment of the real conditions existing.

The policy of erecting a high smoke stack, which was adopted by the Tennessee Company in 1906, was not followed by the Ducktown Company. The main stack of their works rises only 90 feet above the smelter yard. Its top is a little below the summits of the hills nearby and 185 feet below that of the top of the Tennessee stack. It seems reasonable that a high stack offers better defense for the Tennessee Company one-half mile from the Georgia line and a low stack for the Ducktown Company two and six-tenths miles further away from Georgia. (See photographs.)

Experiments for Utilizing the Sulphur Dioxide of the Smoke

There is much to show that the Ducktown Company acted in good faith in an endeavor to install appliances and apparatus "to eliminate the fumes and gases com-

plained of," the grounds stated for the postponement from time to time by the State of Georgia of the motion for final decree. That the company looked to the utilization of the sulphur, as well as of the copper and iron of the ores, is indicated by the title adopted at the organization in 1891, "The Ducktown Sulphur, Copper & Iron Company, Ltd." The conversion of the sulphur dioxide of the smoke into sulphuric acid appeared to offer the best prospect for accomplishing this purpose. Preliminary experiments were made in 1905 and 1906 with the contact method of manufacturing sulphuric acid. A ten-ton plant was erected and the process tried in 1907 and 1908 at a cost of $60,000. This method of making sulphuric acid, which had been used successfully with gases richer in sulphur dioxide, was found to be impracticable with the gases issuing from the pyritic smelting of the copper ore of the Ducktown region. The contact plant was abandoned.

The chamber acid plant now used was erected in 1908 and 1909 at a cost of more than $500,000. It was put into operation in June, 1909. Improvements and enlargements up to the present time have added $100,000 to the cost. In the endeavor to convert a greater percentage of the ore into sulphuric acid, a McDougal roaster was erected and tried in 1913 and 1914. The cost of this was $20,000. It is no longer in use. At the same time as the roaster, the flotation method, now used successfully with zinc ores, was tried. Copper ores treated by this method can then be smelted, or they can be reduced by leaching or precipitation without the evolution of sulphur dioxide. The flotation plant, which was put in operation at a cost of $10,000, was destroyed by fire last September.

One of the most interesting experiments made by

the Company has for its object the utilization of the sulphur dioxide of the smelter fumes in the manufacture of elemental sulphur. This method, which involves the use of an electric furnace, was patented May 13, 1915, by W. F. Lamoreaux and C. W. Renwick. It was tried on a small scale in 1914. In the summer and fall of 1915 a plant was built which is calculated to make three tons of sulphur a day. It has been running almost continuously since the last of October. The cost has been nearly $30,000. It can be enlarged at a much smaller cost proportionately. Whether this venture will, like several others, be a failure or be used along with the sulphuric acid method or prove so successful as to replace the latter, is yet to be determined.

Is Vegetation Within the Vicinity and in the State of Georgia Injured by the Gases from the Ducktown Company's Plant as it is Now Operated?

Conditions have improved since 1907. The amount of ore smelted at that time by the Ducktown Company was as great as now, or greater. Then all of the sulphur in the gases emitted escaped into the atmosphere; now more than 50% of the sulphur in the gases is utilized in the manufacture of sulphuric acid. The company claims that the amount escaping now is so small that no injury is done to vegetation. The testimony of many witnesses goes to prove that injury is done; of many others, that it is not. The inspector has been asked to study the question and give an opinion.

How the Smoke Injures Plants

Since plants get nourishment both through the soil by means of their roots and through the atmosphere by means of their leaves, they might be starved or poisoned through either medium. The smoke, therefore, might be expected to injure plants either (1) indirectly by impoverishing or poisoning the soil about the roots, or (2) directly by attacking the leaves. Both the mineral constituents of the smoke in the fume and its oxides of sulphur in the gases are frequently brought down to the earth by the force of gravity or by rain and snow, and become components of the soil.

By referring to table 2, it may be seen that *the fume,* which is practically the same as the bag house precipitate, *consists principally of oxygen and sulphur compounds of zinc and lead.* It contains no arsenic. In this respect it differs greatly from the fume of copper smelters in the western states, which consist principally of lead compounds and arsenic. It is not probable that the soil in the Ducktown region is rendered materially less productive or injurious to vegetation by the minute quantity of zinc and lead compounds it acquires from the smoke. Very careful analyses made by the Selby Commission showed only doubtfully an increase in the percentage of lead in soil exposed to fume of much higher lead content than that of the Ducktown Sulphur Company's smelter.

The sulphur dioxide of the smoke comes into the soil as sulphurous acid or oxidized to sulphuric acid. The mineral bases of the soil combine with the acids to form salts—probably sulphates altogether. The soil of the Ducktown basin may contain a slightly greater percentage of sulphates than it did twenty-five years

ago, but these are not generally injurious to the soil; some of them are advantageous. If the soil should happen not to contain a sufficient amount of bases to neutralize the sulphuric acid, then any injury to the plant might be prevented at little cost by the addition of lime.

Sulphur Dioxide the Chief Cause of Injury

The chief injury to plants is generally conceded to come through the leaves by contact with the smoke. The constituents of the fume—the visible part of the smoke—are not the chief agents of injury. They are comparatively innocuous in the small quantities in which they exist in the highly diluted smoke. Leaves are not affected by a water extract of the fume containing many times as much of the soluble constituents of the smoke as is likely to be deposited on the leaves even in a dense smoke.

It has been established by investigations carried on in Germany for many years and by recent experiments in the United States that sulphur dioxide is the constituent of sulphuretted fumes most injurious to vegetation. When absorbed by the leaves of the plant it undergoes oxidation and is converted into a sulphate; yet the leaves are not so sensitive to sulphur trioxide fumes as to those of sulphur dioxide. Taking this into consideration and, in addition, the fact that analysis of the Ducktown smelter smoke shows no free sulphuric acid present, or scarcely any, no further account need be taken of sulphuric acid, and the question is narrowed to injury by sulphur dioxide in the smoke.

Smoke from Two Smelters

The solution of the problem is complicated by the fact that there are two smelters in this region and that during the period of this investigation the smoke from either furnace has probably at some time reached every locality in the Ducktown basin. The finding of injury by smoke entails the further question "Which smoke?"

The smelter of the Tennessee Company at Copper Hill is much the larger of the two; but this company claims (1) that a greater proportion of the sulphur is eliminated by its acid plant than is the case with the Ducktown company, (2) that the fumes issuing from its very high stack are so much diluted before they reach the ground that they are harmless to vegetation.

The smoke stack at the smelter of the Ducktown company does not quite reach to the level of the hills in the vicinity, so that this company claims that if any damage is done to vegetation it must be in the vicinity,—certainly not so far away as the State of Georgia.

The inspector had no authority to investigate the operation of the Tennessee Company's works and, consequently, the actual amount of the sulphur escaping in the gases emitted from these works being unknown, an inference could not be drawn by comparing the quantity of sulphur in the fumes escaping from the smelters of the two companies. It seemed that comparison might be made by determining separately the actual amount of sulphur dioxide present in the track of the smoke from these plants at various distances when the wind was blowing in such direction that there would be no doubt of the source of the smoke. It appeared desirable also that

PLATE III

1—Looking N. NE. from the hill E. SE. of the smelter: A—Potato Creek, B—Staff House, C—Capt. Nolde's residence, D—Stansbury Mountain.

2—Looking NW. from Staff House: A—East Tennessee mine, B—Little Frog Mountain—in the rim of the Basin, C—Capt. Nolde's residence.

3—Looking NW. A—Observing Station, B—Acid Plant.

daily observations be made of the trend of the smoke and the region it appeared to reach in order that it might be known in case of injury to vegetation in a certain locality, from which smelter the smoke was coming at the time the injury occurred.

The Observing Station

To facilitate work of this kind, a small tower was erected as an observing station on a hill at an elevation of 1785 feet, 600 yards, four degrees west of south from the smelter at Isabella and two and three-tenths miles from the smelter at Copper Hill.

The station was equipped with a weather vane, anemometer, barometer, thermometer, psychrometer, and the apparatus and chemicals needed for making sulphur dioxide determinations. The iron rod supporting the weather vane and anemometer above the roof passes down into the room and through the center of a table on which is a "Ducktown Special" topographical map adjusted to the points of the compass. Just above the map is a steel pointer running horizontally through the rod, fixed parallel to the vane and moving with it. With the two smelters as centers, circles were drawn on the map at one-fourth, one-half and one mile intervals, so that the distance and direction from the smelters of any point in the circumscribed area could be told at a glance.

From the observing station the plants of the Ducktown and Tennessee companies are both visible, and practically the whole Ducktown basin to the rim of mountains that surround it. The trend of the smoke from either smelter and its sweep could be seen for

miles, and points for making sulphur dioxide judiciously selected.

Because of engrossment of our time by other work and the difficulty of getting a competent and reliable man in the vicinity to make observations, the station was not used as much as anticipated. While a series of sulphur dioxide determinations there coincident with weather and smoke observations would have been useful, analyses made rapidly in the field at various points seemed preferable.

Method of Determining Sulphur Dioxide

Not a sufficient number of the factors and their relative influence are ever known to enable one to calculate the percentage of dioxide present in the atmosphere at a place on the surface of the earth whose elevation is known and its distance from the smelter from which the gas is coming. One may ascertain the percentage and quantity of the sulphur dioxide in the smelter smoke, its temperature and velocity as it issues from a stack of known height, the pressure, temperature, and humidity of the air, the velocity of the wind,—all of them factors great or small—yet find it impossible with these to solve the problem accurately. These aid in making an approximate estimate, but actual determinations chemically is the only means of getting reliable results.

Some time was spent in reading and experimenting in order to find a satisfactory method for determining very small amounts of sulphur dioxide in the atmosphere. The method finally adopted was the one used by the Selby Smelter Commission in an investigation carried on last year in Solano county, California, proof sheets

of which we had the privilege of seeing through the kindness of the Director of the Bureau of Mines, Washington, D. C. In this method the sample of air is collected in twenty-four liter bottles, partially evacuated by means of an air pump. The determination is made by means of $\frac{1}{500}$ normal solutions of iodine and sodium thiosulphate with a specially prepared starch solution as an indicator. This is checked by blank test with a similar bottle under exactly the same conditions, the color of the starch iodide in the two tests being brought to the same tint. We used ten-liter bottles and exhausted them to contain six liters of air, the number of inches of mercury necessary for each temperature and pressure being read from a calculated table on a card tacked near the barometric scale.

For reaching distant points quickly, an automobile was used with the steps strengthened and fitted with attachments so as to carry without jostling the boxes containing the apparatus for the sulphur dioxide determinations. Two sets of the apparatus in four boxes were carried, the air pump being on one of the boxes and used without removal. Everything necessary for the determination was enclosed in the boxes, and a sample could be taken and an analysis made in a few minutes.

Field Work in Sulphur Dioxide Determinations

Experiments were begun August 25th at the observing station, and in the field with the car August 27th, 1915. The work was extremely interesting to those engaged in it, and was carried on from day to day continuously whenever weather conditions appeared to

offer opportunity for obtaining data of value, and the records were made carefully, conscientiously, and as accurate as possible. From observations every morning a plan of operations for the day was made, the selection of locality depending upon weather conditions and the purpose in view. At first we planned to make determinations of sulphur dioxide for comparison at places when the smoke was coming from either smelter and again when it was coming from both; and we hoped to cover practically the whole field where the charge of smoke injury was made; but soon it was seen that this could not all be accomplished in the time at our disposal, so it was decided to make a point of determining the sulphur dioxide in as many samples as possible collected in the region between Isabella and Georgia at times when the wind was blowing the smoke from the Ducktown company's smelter toward Georgia. This would eliminate the smoke from the Tennessee Company's plant as a factor, provided the samples were not taken too soon after the wind had changed from a southerly to a northerly direction. A sufficient number of such analyses made at different distances from the source of smoke and under various conditions of wind and weather and sulphur dioxide output of the smelter ought to supply the necessary data for calculating the rate of diffusion and the degree of dilution of the gas at points within the vicinity and in the State of Georgia. Samples collected when the wind was in any direction except from the south, southeast, and southwest, might be used for the same purpose, provided care was taken to see that there was no admixture of the smoke from the two smelters. For comparison, the samples were taken whenever possible in

the midst of the cloud of smoke. In carrying out this plan of operation a sample would be taken near the smelter and then the car be run as rapidly as possible in the direction the smoke was going and successive analyses made as long as any sulphur dioxide could be detected in the air.

Sudden changes in the direction of the wind interfered greatly with the work. Often while we were preparing for an experiment in the midst of the smoke stream, the wind would veer and the smoke would be seen passing at some distance. Sometimes the results of analyses made at or near the same place and time will be found to differ considerably on this account—one sample having been taken in the smoke stream, the other at the margin or outside of it. Near the smelter when the wind is not strong and steady it may appear to blow at short intervals from various points of the compass because of temporary local currents and eddies.

Apparently another cause of difference in results of determinations nearly coincident, but of less consequence than sudden changes in the direction of the wind, is the variation in concentration due to waves of condensation and rarefaction in the smoke stream. This was especially noticeable in the smoke from the high stack of the plant at Copper Hill when seen from the observing station at right angles to the line of motion; and it was not unusual in the field for the men with the collecting bottles to wait for the coming of the denser smoke seen approaching.

What effect the topography of the country in the vicinity of Isabella has upon the density of the smoke issuing from the plant of the Ducktown Company has been much discussed. The opinion of the inspector

with reference to this question is based more on observation than experiment.

The smelter is situated at the junction of the narrow valleys of Potato Creek and Stewardtown Creek. The smoke stack does not rise to the level of the tops of the hills nearby; but ordinarily when the smoke is issuing freely from the stack it rises above the hills and moves over them without much obstruction. The smoke escaping from the top of the furnace, which much of the time during small output seems the greater quantity, comes out of the smelter shed more diffused than the stack smoke and has a tendency to drift along the valley running nearest the direction the wind is moving, i. e., northeast up Potato Creek, southeast up Stewardtown Creek, southwest down Potato Creek. In certain conditions of the atmosphere, e. g., during a fog, this is true of the smoke from the stack also. These statements must not be construed to imply that the smoke may flow down the narrow, crooked valley of Potato Creek and by reason of this channel be capable of doing injury to vegetation across the Ocoee river in Tennessee and Georgia. (See Plate 4.)

Several experiments will be found in table VI in which for comparison samples were taken simultaneously at the top and bottom of a hill toward which the smoke was coming or on a ridge and in a valley nearby, but the results in such cases depend so much on whether the smoke is coming from the furnace or the stack, the distance from the smelter, weather conditions, etc., that each experiment requires exact statement of the circumstances for trustworthy interpretation.

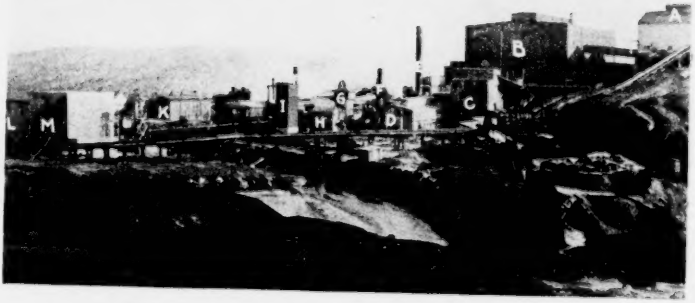


PLATE IV

1—Looking N. from the valley of Fightingtown Creek, showing the high stack of the Tennessee Copper Company plant.

2—Looking SW. from Staff House.

A—Staff House Bridge.
B—Ducktown Co. Ry.
C—Power House.
D—Steam Condenser.
E—The Ducktown Company's Plant.
F—Big Frog Mountain—in the rim of the Basin.
G—Shaft House, Burra Burra mine.

3—Looking East, The Ducktown Co. Plant: A—Acid House, B—Tower House, C—McDougal Roaster, D—Blower House, E—Main Stack, F—Emergency Stack, G—Cottrell Precipitation Plant, H—Transformer House, I—Bag House, K—Store and Office Building, L—Condenser and Electric Furnace House, M—Sulphur Condensing Chamber.

Explanation of Table 6

The original record contains the number of cubic centimeters of iodine used in the experiment and the temperature and pressure of the air at the time of making the determination. In a few of the experiments the humidity of the air was taken by a psychrometer. The direction and velocity of the wind were estimates generally, and may be considered only approximately correct. A "Ducktown Special" topographical map was used to ascertain location and get direction and distance from the Ducktown Company's smelter. These can be readily found by referring to the map—Plate 2. Fifty-three of the missing numbers are of experiments made in Tennessee and Georgia when the smoke was coming partly or wholly from the smelter of the Tennessee Company. The other numbers missing are those of experiments discarded, not because of apparent discrepant results, but because of something pertaining to them that threw doubt upon their correctness.

Under the heading Weather, S & C means "sun and cloud."

TABLE 6

DETERMINATION OF SULPHUR DIOXIDE IN THE ATMOSPHERE IN THE VICINITY OF THE DUCKTOWN COMPANY'S SMELTER

A. Readings by C. S. Williamson, Jr., and J. B. Overstreet
August 25 to September 25, 1915

Test No.	*Date Time*	*Weather*	*Wind direction and velocity*	*Sulphur dioxide escaping tons*	*Parts per million*	*Location and Remarks (Distance reckoned from D. S. C. I. Company's smelter.)*
	Aug. 25			*20.8*		
1	10:30	Hazy	E. NE 3		1.49	600 yds. S. at Observing Station.
2	4:40	Fair	E. NE 12		0.56	600 yds S. at Observing Station.
	Aug. 26			*10.1*		
3	10:30	Fair	W. NW 5		1.67	Same place as above.
	Aug. 27			*13.4*		
4	11:30	Cloudy	South 8		5.36	150 yds. N. Isabella mine, top of hill.
5	11:30	Cloudy	South 8		8.56	150 yds. N. Isabella mine, bottom of hill.

TABLE 6—*Cont'd*

Test No.	*Date Time*	*Weather*	*Wind direction and velocity*	*Sulphur dioxide escaping tons*	*Parts per million*	*Location and Remarks (Distance reckoned from D. S. C. I. Company's smelter.)*
	Aug. 28			*12.5*		
12	9:35	Cloudy	N. of W 12		0.37	1800 yds. Stewardtown on hill above Angelico Rd. Odor slight.
13	9:56	Cloudy	N. of W 9		0.37	1650 yds. Angelico Rd. at turn to Bonnertown. No odor.
14	10:20	Cloudy	N. of W 14		0.00	2¼ mi. One-half mi. from Angelico Gap on Stewardtown Creek.
15	10:50	Cloudy	N. of W 14		0.37	400 yds. Forks of Copper Hill and Stewardtown Rd. at bridge. Slight odor.
16	11:15	Cloudy	West 14		0.37 5.86	400 yds. (1) On hill SE. of post office in edge of smoke. 400 yds. (2) In the smoke.
17	11:50	Cloudy	N. of W 13		0.37	600 yds. S. at Obs. Sta.
18	2:15	S. & C.	NW 13		335.00	On bunkers against wall of charging floor. Almost overcome by smoke in taking sample.
19	2:15	S. & C.	NW 13		35.5	100 feet further S. on bunkers than No. 18.
22	4:00	S. & C.	N. NW 10		0.93	1440 yds. SE. on Mineral Bluff Rd.
23	4:20	S. & C.	N. NW 6		0.19	200 yds. NW. on Ducktown Rd. on hill bet. Potato Creek and Burra Creek.
24	4:45	Hazy	N. NW 6		0.93	800 yds. on Copper Hill Rd. Slight odor.
25	5:30	Hazy	N. NW 8		0.56	1650 yds. on Copper Hill Rd. E. of Potato Creek.

NOTE.—This day very little smoke issued from D. S. C. I. plant as judged by the eye.

	Aug. 30			*21.3*		
26	9:15	Foggy	NE 6		0.38	2000 yds. at Staff-House, front yard towards smelter. No odor.
27	9:50	Cloudy	North 15		0.19	800 yds. S. of E. of Obs. Stat. on Copper Hill Rd. Odor slight.
28	10:00	S. & C.	North 15		2.47	800 yds. Same place as No. 27. Odor strong.
29	10:20	Clear	North 15		2.23	800 yds. Same place.
30	10:30	S. & C.	North 15		2.23	800 yds. Same location.
31	1:25	Cloudy	North 15		3.72	300 yds. S. of machine shop on hill. Matte charges to-day.
32	1:30	Cloudy	North 18		0.93	800 yds. SE. of Obs. Sta. on Copper Hill Road.
33	2:25	S. & C.	North 17		0.37	3700 yds. SE. one-fourth mi. from Quinn's orchard.
34	2:25	S. & C.	North 17		0.37	3700 yds. Same place.
35	2:45	S. & C.	North 15		0.19	3700 yds. Same place. Very slight odor.
36	2:45	S. & C.	North 15		0.19	3700 yds. Same place. Very slight odor.

TABLE 6—*Cont'd*

Test No.	*Date Time*	*Weather*	*Wind direction and velocity*	*Sulphur dioxide escaping tons*	*Parts per million*	*Location and Remarks (Distance reckoned from D. S. C. I. Company's smelter.)*
	Aug. 30			*21.2*		
37	3:30	Fair....North	13		0.37	2475 yds. One mi. N. of Coletown. Gas thick. Odor strong.
38	3:40	S. & C..North	13		0.37	2775 yds. SW. of location of No. 37 on hill.
39	4:00	S. & C..NW	15		0.00	2775 yds. SE. of No. 37, in valley in bed of creek about 300 yds. E. of N. of Belltown.

NOTE—This day smoke seemed to stick to the ground, although appearing in light clouds, small percentages of sulphur dioxide were found at a distance of over a mile from the D. S. C. I. furnace. There was no contamination of smoke from the Tennessee Company's smelter, as the wind was from a northerly direction and blew both smokes southerly, and no tests were made south of the Tennessee Company's plant.

	Sept. 3			*20.0*		
62	1:30	S. & C..E. of N	5		171.58	On bunkers close up to wall of charging floor.
62a	1:30	S. & C..E. of N	5		73.75	100 feet further out on bunkers.
63	2:10	Fair....North	8		1.12	800 yds., 150 yds. E. of Obs. Sta. Smoke in the valley on E. side.
63a	2:10	Fair....North	8		0.00	Within a few feet of No. 63.
	Sept. 4			*21.7*		
68	9:35	Cloudy .NE	4		1.30	150 yds. W. of S. of smelter.
69	9:35	Cloudy .NE	4		1.30	200 yds. W. of S. of smelter.
70	9:40	Cloudy .NE	4		1.67	500 yds. down the hill from Obs. Sta.
70a	9:40	Cloudy .NE	4		3.63	500 yds. Smoke seemed high, yet showed amount on the ground.
71	9:50	DrizzlingNorth	6		5.77	300 yds. midway between smelter and Obs. Sta. Odor strong; smoke thick.
72	9:55	DrizzlingNorth	6		0.74	700 yds., 100 yds. SE. of Obs. Sta. Odor. Sample taken on edge of smoke column.
73	10:10	DrizzlingNorth	6		1.11	600 yds. at Obs. Sta. Odor strong in midst of smoke.
74	10:35	DrizzlingW. of N	6		0.74	1000 yds. at slag dump SE. of Obs. Sta. Column of smoke had just passed. Slight.
75	11:00	DrizzlingW. of N	4		0.18	800 yds. on Copper Hill Rd. midway bet. Obs. Sta. and slag dump toward Tenn. Co. plant. No odor. Smoke column had just passed.
76	11:35	DrizzlingNorth	5		0.37	2000 yds., one-half mi. from Mary mine toward Isabella on Copper Hill Rd. Slight odor possibly.

TABLE 6—*Cont'd*

Test No.	*Date Time*	*Weather*	*Wind direction and velocity*	*Sulphur dioxide escaping tons*	*Parts per million*	*Location and Remarks (Distance reckoned from D. S. C. I. Company's smelter.)*
	Sept. 4			*21.7*		
77	11:35	Cloudy	North	7	0.28	2¼ mi. W. of S.
78	11:35	Cloudy	North	7	0.19	Same place.
	NOTE.—Nos. 77 and 78 were 500 yds. S. of Coletown in cove on road and on hilltop, respectively. No odor in either case, yet both in direct line of smoke and smoke could be seen passing.					
79	12:00	S. & C.	North	7	0.38	2¼ mi. South, one-half mi. SE. of Coletown on hill.
80	12:05	S. & C.	North	7	0.76	A few yds. from No. 79. Odor.
	Sept. 6			*21.3*		
89	9:00	Fog	Still		4.93	100 yds. E. by chemical laboratory. Strong irritating odor.
90	10:00	Fair	Still		2.42	100 yds. S. by garage opposite supply house. Substantial odor. Fog had practically cleared away except at distance.
91	10:20	Fair	Still		0.19	300 yds. in road bet. power plant of D. S. C. I. and Staff House. If anything, there was a slight breeze from north.
92	10:35	Fair	Still		4.88	150 yds. E. NE. by garage of D. S. C. I. east of chem. lab. If anything, slight breeze from W. Odor strong.
93	10:50	Fair	W. of S		0.00	1200 yds. beyond Stewardtown on Angelico Gap Rd. No odor.
94	11:00	Fair	SW	2	0.00	900 yds. NE. in rd. on bridge at foot of hill leading to Staff House. No odor.
95	11:40	Fair	SW	5	0.19	1200 yds. E. NE. on hill opposite Staff House across Potato Creek.
96	11:45	Fair	SW	6	1.12	500 yds. E. above post office on hill. Strong odor.
99	4:00	Fair	NW	5	6.32	500 yds. S. on hill at bridge on Copper Hill Rd. Smoke thick and odor strong.
	Sept. 6			*21.3*		
100	4:15	Fair	NW	5	1.30	Same location as No. 99 except in bed of branch.
101	4:50	Fair	North	5	0.00	800 yds. SW. on hill on Mineral Bluff Rd. Before test could be made smoke had shifted.
102	5:10	Fair	NW	5	4.28	400 yds. on hill above Stewardtown. Smoke had cleared away except that hanging close to ground. Odor moderately strong.

TABLE 6—*Cont'd*

Test No.	*Date Time*	*Weather*	*Wind direction and velocity*	*Sulphur dioxide escaping tons*	*Parts per million*	*Location and Remarks (Distance reckoned from D. S. C. I. Company's smelter.)*
	Sept. 7			*18.4*		
103	8:30	Foggy	NE 2		0.28	2000 yds. in front of courthouse at Ducktown; 12 liters of air used in this test.
104	9:30	Fog. sun	Still		0.56	1700 yds. on Ducktown Rd. Fog clearing away; 12 liters used.
105	9:45	Fog. sun	NE 2		2.50	400 yds. W. in valley. No odor. 12 liters used.
106	9:15	Fog. sun	NE 3		2.79	400 yds. W. on railroad in creek bed.
107	10:00	Fog. sun	NE 2		3.55	Same place. Wind very changeable.
108	10:15	Fog. sun	SW 3		2.05	200 yds. N. Odor slight. Wind blowing smoke apparently a little east of point taking sample.
109	10:25	Almost clear	SW 2		1.30	200 yds. NE. on Staff House Rd. Odor perceptible. Smoke seemed to be settling. Sun shining but fog still present.
110	10:40	Almost clear	SW 2		1.30	900 yds. on bridge at foot of Staff House hill. Odor slight.
111	10:55	Almost clear	SW 4		0.47	1100 yds. NE. front of Mr. Wallace's house in creek bed.
112	1:30	Clear	SW 4		0.00	100 yds. N. No odor. Wind too much E.
113	1:40	Clear	SW 5		0.00	200 yds. NE. Same conditions as No. 113. No odor.
	Sept. 8			*19.4*		
127	4:00	Clear	NW 8		1.21	1000 yds. in road 500 yds. SE. of Obs. Sta. Odor slight.
128	4:00	Clear	NW 8		1.30	Same location except on hill instead of in road.
129	4:30	Clear	North 7		2.23	100 yds. S. on Copper Hill Rd. Odor apparent.
	Sept. 9			*15.5*		
137	3:00	Clear	NE 8		0.36	100 yds. S. front of garage by supply house. Odor apparent. Very little smoke issuing from the plant.
	Sept. 10			*20.9*		
140a	8:15	Clear	SW 3		2.79	300 yds. NE. on bridge in Ducktown Rd. Odor apparent.
140b	8:15	Clear	SW 3		1.48	Same place, in valley below road in the creek. Odor apparent.
141a	8:35	Clear	SW 3		2.42	Same location as No. 140a.
141b	8:35	Clear	SW 3		1.86	Same location as 140b except on hill.
142a	9:05	Clear	SW 3		2.42	200 yds. NE. of smelter, beyond power plant. No odor.

TABLE 6—*Cont'd*

Test No.	*Date Time*	*Weather*	*Wind direction and velocity*	*Sulphur dioxide escaping tons*	*Parts per million*	*Location and Remarks (Distance reckoned from D. S. C. I. Company's smelter.)*
	Sept. 10			*20.9*		
142b	9:05	Clear...SW	3		1.86	Same location. No odor.
143a	10:00	Clear...SW	3		0.37	300 yds. on Copper Hill Rd., on bridge.
143b	10:00	Clear...SW	3		0.56	Same as 143a except on hill. Slight odor.
144a	10:20	Clear...SW	6		0.56	900 yds. at foot of Staff House hill on bridge.
144b	10:20	Clear...SW	6		1.48	Same location, except on hill.
145	10:35	Clear...SW	6		1.67	200 yds. between power plant and Staff House. Odor pronounced.
146	10:40	Clear...SW	5		10.79	100 yds. in road S. of post office, Isabella. Strong odor.
147	11:00	Clear...NW	8		1.30	800 yds. Stewardtown. No odor.
148a	12:00	Clear...NW	7		8.56	100 yds. from smelter by garage at chemical laboratory.
148b	12:00	Clear...NW	7		6.32	100 yds. from smelter on hill above post office. Strong odor at both.
149	12:15	Clear...NW	8		4.28	75 yds. near post office. Wind not quite direct from smelter.
150	2:15	S. & C..NW	8		348.28	On charging floor of the smelter. View befogged by smoke.
151a	3:15	S. & C..N. of W	8		2.05	200 yds. E. on top of hill beyond chemical laboratory.
151b	3:15	S. & C..N. of W	8		5.95	Half way up the hill.
152a	3:45	S. & C..N. of W	10		0.93	400 yds. on Potato Creek East, opposite Staff House Rd., near top of hill.
152b	3:45	S. & C..N. of W	10		3.72	30 yds. further down the hill. Strong odor here.
154	4:50	Clear...NW	10		1.42	800 yds. in Stewardtown.
155	5:10	Clear...North	8		0.56	1650 yds. S. or a little east of S. on branch. Slight odor.
	Sept. 11			*14.0*		
156	8:00	Fog.....E. of S.	still		1.50	At the Staff House, north end by the steps. Thrown out on account of starch not acting properly.
157	8:35	Fog.sun.E. of S.	1		6.14	1100 yds. NE. of smelter, at Capt. Nolde's house. Strong odor and acrid taste. Strong odor had been observed at Staff House at 3 or 4 o'clock in the morning.

TABLE 6—*Cont'd*

Test No.	*Date Time*	*Weather*	*Wind direction and velocity*	*Sulphur dioxide escaping tons*	*Parts per million*	*Location and Remarks (Distance reckoned from D. S. C. I. Company's smelter.)*
	Sept. 11			*14.0*		
158	9:00	Fog.sun.E. of S	1		4.09	1300 yds., 200 yds. further up valley than No. 157. Odor still persistent and acrid taste.

NOTE.—After making the last test we drove north on the Isabella Pack Gap road. On the way up smoke was observed to be passing close to the ground south, as if carried by an undercurrent. In the distance toward Stansbury Mt. the same phenomenon was observed. The wind overhead was distinctly northerly, and smoke from the D. S. C. I. smelter was traveling northerly, yet low down, as stated above, the smoke was moving southerly. This may account for the heavy odor at Staff House on foggy nights and mornings when the wind is S. of E., the smoke from either the D. S. C. I. or Tennessee Co. plant being banked against mountains and pulled backward by undercurrents.

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159	9:15	Clear...South	3		0.37	800 yds. Copper Hill Rd.

NOTE.—This is residual smoke from that travelling south mentioned in note following No. 158. The smoke was still travelling south and passed us before we could get apparatus fixed, although we drove well beyond the edge of it.

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160	9:35	Clear...SW	5		3.72	100 yds. N. on Ducktown Rd. at bridge. Very slight odor.
161	10:15	Clear...NE	5		3.72	100 yds. from smelter, by chemical laboratory. Smoke visible.
162	10:45	Clear...NE	8		3.35	200 yds. W. Very little smoke. Slight odor.
163	1:55	Clear...N. of W	10		9.60	100 yds. by garage opposite supply house.
164	2:30	Clear...N. of W	10		2.60	400 yds. Copper Hill Rd. Odor, but not strongest at time of taking sample.
165	2:50	Clear...N. of W	8		5.20	Same location as No. 164. Odor stronger.
166	3:20	Clear...NW	10		1.02	1000 yds. S. E. on hill, elevation 1,743 feet. Odor apparent.
167	3:55	Clear...North	11		0.47	1200 yds. on private road leading to "pest houses" near railway track, 200 yds. SW. of No. 166.
168	4:15	Clear...North	10		0.47	1200 yds., a little NW. of No. 167. Odor slight.
169	4:45	Clear...North	10		0.00	1650 yds. Almost directly S. or a little E. of S. No odor.
	Sept. 13			*22.0*		
170	9:30	Clear...SW	2		0.37	150 yds. NE. Smoke high (500 ft.). Slight odor.
171	10:00	Clear...SW			0.37	3300 yds. NE. on Potato Creek at foot of Mountain on crest of hill near Bald Mt. No odor.
172	10:30	Clear...South.....			0.00	4100 yds. NE. foot of Stansbury Mt. on promontory.

NOTE.—This test should have shown gas if there was any lurking here, as on approach it is as if the gas were hanging here and had looked so for some time.

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TABLE 6—*Cont'd*

Test No.	*Date Time*	*Weather*	*Wind direction and velocity*	*Sulphur dioxide escaping tons*	*Parts per million*	*Location and Remarks (Distance reckoned from D. S. C. I. Company's smelter.)*
	Sept. 11			*14.0*		
173a	11:20	Cloudy	South.....		12.65	100 yds. N. across creek on Ducktown Rd.
173b	11:20	Cloudy	South.....		15.81	Same location. Gas high, but not so high as earlier.
174	12:00	Drizzling	South.....		3.81	200 yds. N. Strong odor.
175	1:00	Cloudy	NW 7		10.04	200 yds. S. On hill. Smoke dense.
176	1:25	Cloudy	N. of W 7		9.30	300 yds. on hill above Copper Hill Rd. Smoke dense.
177	1:45	Drizzling	NW 7		5.02	500 yds. SE. on ridge above Stewardtown. Smoke dense.
	Sept. 13			*22.0*		
178	2:20	Rain	S. of E 10		2.69	800 yds. NW. on Ducktown Rd. Smoke dense.
179	2:55	Cloudy	NW		0.00	This test shows nothing as gas had changed direction before taking sample.
181	5:00	Cloudy	SW 4		0.93	1600 yds. NW., SE. of Ducktown at Tennessee Co.'s tracks by bridge. Apparently not in direct line of smoke.

NOTE.—This day's work was run out in the attempt to get curve for a matte charge. During the day, on account of a "sow" in smelter, gases seemed denser than usual at the furnace. On account of the changeableness of the wind, it was very difficult to get the tests at consecutive and regular distances; and in the afternoon, on account of disarrangement of apparatus, one or two tests were lost. WILLIAMSON.

B. Readings made by Howard E. Palmer
September 18 to October 3, 1915

	Sept. 18			*18.0*		
1	8:15	Foggy	Still.....		2.6	1100 yds. NE. at Staff House.
2	8:45	Fog lftg.	North1 or 2		1.8	Same place. Odor distinct in 1 and 2.
3	9:15	Clearing	North2 or 3		0.2	Same place. Odor very faint, if any.
4	9:45	Clear	North3 or 4		0.0	Same place. No odor.
5	10:15	Clear	North3 or 4		0.0	Same place. No odor.
	Sept. 21			*19.6*		
6	10:00	Clear	N. NW 10		1.1	880 yds. SE. between Copper Hill Rd. and railroad. Odor fairly strong.
7	10:30	Clear	N. NW 12		0.2	1300 yds. SE. on hill SE. of railroad track. Odor very faint, if any.
8	10:45	S. & C.	N. NW. 10		0.0	1400 yds. S. SE. in valley. No odor.
9	11:05	S. & C.	N. NW. 12		0.2	1300 yds. S. SE. on top of hill directly in line of smoke. Odor very faint, if any.

TABLE 6—*Cont'd*

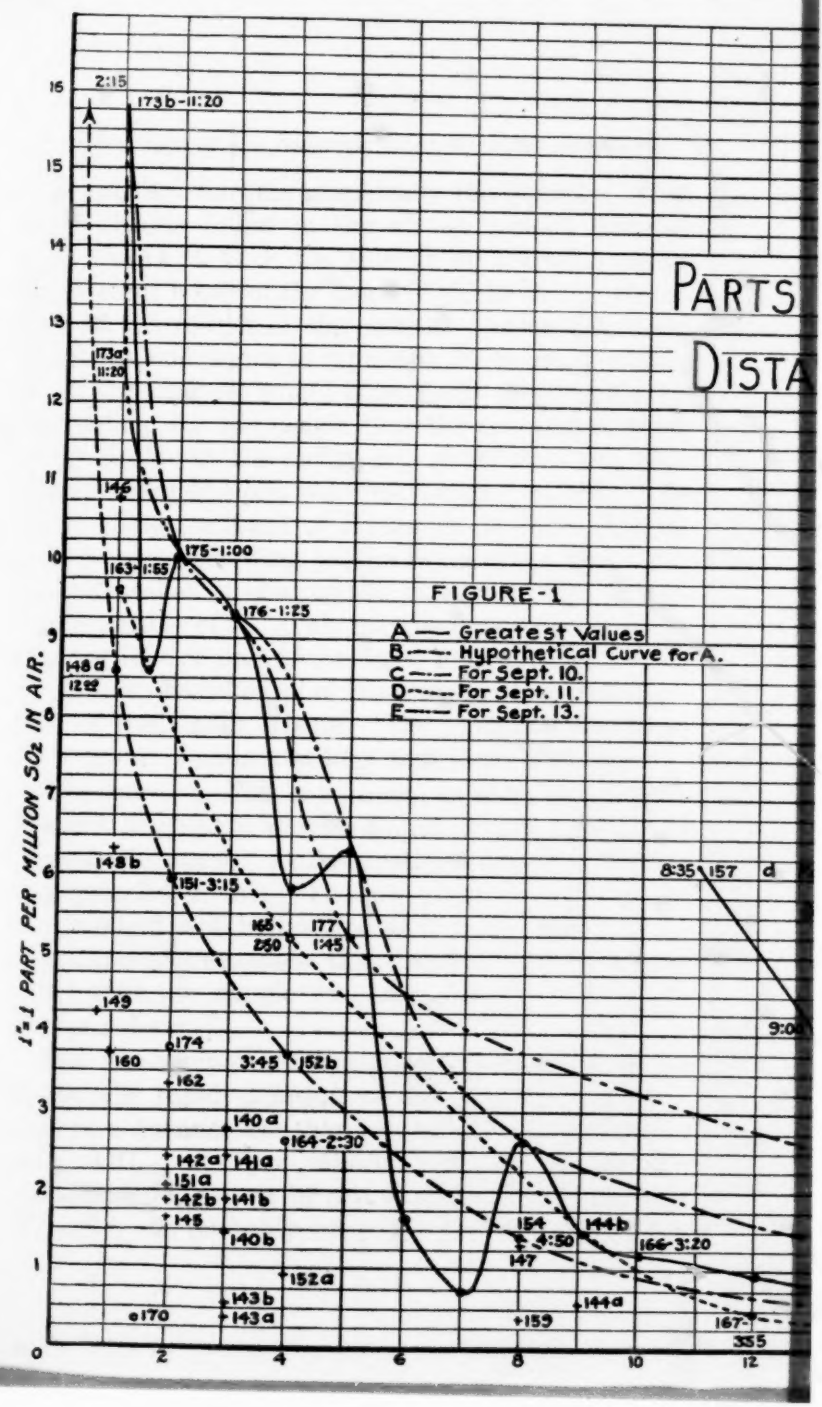
Test No.	*Date Time*	*Weather*	*Wind direction and velocity*	*Sulphur dioxide escaping tons*	*Parts per million*	*Location and Remarks (Distance reckoned from D. S. C. I. Company's smelter.)*
	Sept. 21			*19.6*		
10	11:25	S. & C.	N. NW. 12		0.1	1300 yds. S. SE. Same place. Odor none.
10a	11:40	S. & C.	N. NW. 14		0.45	1500 yds. S. SE. Odor very faint.
11	2:05	Clear	N. NW. 15		0.1	2600 yds. S. SE. No odor.
12	3:25	Clear	N. NW. 15		0.0	2600 yds. S. SE. About 100 yds. S. of No. 11. No odor.
13	3:05	Clear	North 16		0.0	500 yds. S. on hill by Obs. Sta. No odor. Probably not in line of smoke.
14	3:30	Clear	North 16		0.9	700 yds. S. near Obs. Sta. Odor fairly strong.
15	4:30	Clear	North 16		0.9	900 yds. S. on Copper Hill Rd. Odor fairly strong.
16	5:00	Clear	North 14		1.5	Same place. Odor fairly strong.
	Sept. 23			*34.7*		
17	7:15	Fog clearing	S. SW. 1		1.5	1100 yds. NE. in valley N. of Staff House. Odor strong.
18	7:15	Fog clearing	S. SW. 1		0.75	1200 yds. NE. on hill 100 yds. NE. of Staff House.
19	9:30	Clear	E. SE. 3 or 4		3.7	250 yds. NW. on Ducktown Rd. Odor fairly strong.
20	10:25	Clear	S. SE. 2 or 3		0.0	2 mi. N. of Tenn. Copper Co.'s smelter in Ducktown Copper Hill Rd. No odor. Smoke high in the air.
	Sept. 27			*28.1*		
21	8:00	Thk. fog	SE. 2 or 3		2.4	1100 yds. NE. on road half way down hill from Staff House.
22	8:35	Fog&sun	Still.....		3.9	1800 yds. NW. in valley NE. of Ducktown E. of Tenn. R. R. track. Odor stronger than before.
23	9:05	Sun&fog	Still.....		3.3	3900 yds. NW. in valley where road from Boonville joins road from Ducktown to Stansbury.
24	9:35	Sun&fog	SE. 4 or 5		0.8	3¼ mi. NW. by N. in valley SE. of L. & N. Ry., one-half mi. S. of Stansbury.
25	10:00	S. & C.	SE. 4 or 5		0.8	4½ mi. N. in road at Zion Hill Church. Test somewhat doubtful.
26	10:25	S. & C.	NW. 6 or 7		0.0	5¼ mi. N. on same road. No odor.
27	10:45	Clear	NW. 5 or 6		0.0	4½ mi. Same place as No. 25.
28	11:00	S. & C.	NW. 3 or 4		0.0	3¼ mi. Same place as No. 24.
29	11:30	S. & C.	NW. 7 or 8		0.0	1800 yds. Same place as No. 22.

TABLE 6—*Cont'd*

Test No.	*Date Time*	*Weather*	*Wind direction and velocity*	*Sulphur dioxide escaping tons*	*Parts per million*	*Location and Remarks (Distance reckoned from D. S. C. I. Company's smelter.)*
	Sept. 28			*30.8*		
30	8:00	Fog clearing	Still.....		0.6	1800 yds. NW. in valley NE. of Ducktow just below the Tenn. Co. R.R.trac
31	8:25	Hazy...	Still.....		2.05	1800 yds. N. on road along Burra Creek W NW. of E. Tenn. mine. Odor fair strong.
32	8:55	Hazy...	Still.....		1.3	1½ mi. N. ¾ of a mi. E. of Boonville i valley of Creek near D. S. C. I. co patch.
33	9:35	Hazy...	Still.....		1.9	2¼ mi. NE. at forks where road runnin foot of Stansbury Mt. branche from road between Ducktown an Stansbury Gap.

NOTE.—Nos. 34, 35, and 36, at 10:05, 10:40, and 11:15, respectively, at points 3⅛ mi. NE 3 mi. NE. and 1800 yds. N. on Burra Creek showed only 0.1 parts sulphur dioxide. This amoun is doubtful, as it represents only one drop of one-thousandth normal iodine.

	Oct. 1			*27.4*		
37	10:20	Cloudy	SW. W. 7 or 8		0.00	1¾ mi. E. NE. on road NE. by E. of Bon ner town. Wind had shifted whe sample was taken.
38	10:45	Cloudy	NW. 9 or 10		3.5	500 yds. NW. of Stewardtown. Odo strong.
39	12:20	Cloudy	W.NW.10to12		0.0	1600 yds. E. SE. on Angelico Gap Rd. Win shifting, but seemed to be blowin direct from plant when sample wa taken. No odor.
	Oct. 3			*38.9*		
40	7:00	Thk. fog	Still.....		1.2	1100 yds. NE., N. of Staff House. Odo fairly strong.
41	7:40	Thk. fog	Still.....		3.0	Same place. Odor strong.
42	8:15	Thk. fog	Still.....		2.5	1100 yds. NE. in valley below Staff House Odor fairly strong.
43	8:40	Sun&fog	Still.....		2.8	1100 yds. NE. north of Staff House. Odo fairly strong.
44	9:00	Fog clrg.	Still.....		3.5	Same place. Odor fairly strong.
45	9:30	Sun&fog	Still.....		3.1	Same place. Odor fairly strong.
46	10:00	Hazy...	Still.....		1.5	Same place. Could not detect odor.
47	10:30	Hazy...	Still.....		1.0	Same place. Smoke from plant risin straight up. No odor.
48	10:55	Hazy...	NW. 1 or less		0.4	1100 yds. NE. in valley SE. of Staff House No odor.
49	11:20	Hazy at E. distance	2 or 3		0.0	1100 yds. NE. north of Staff House. Odo none.


PARTS
DISTA
FIGURE-1
A — Greatest Values
B — Hypothetical Curve for A.
C — For Sept. 10.
D — For Sept. 11.
E — For Sept. 13.
1 = 1 PART PER MILLION SO_2 IN AIR.
2:15
173b-11:20
173a* 11:20
146
175-1:00
163-1:55
176-1:25
148a 12:22
148b
151-3:15
168 2:50
177 1:45
149
160
174
162
3:45
152b
140a
164-2:30
142a
141a
151a
142b
141b
145
140b
152a
143b
143a
170
154
4:50
147
144b
166-3:20
144a
159
167
8:35
157
d
9:0
0
2
4
6
8
10
12
1
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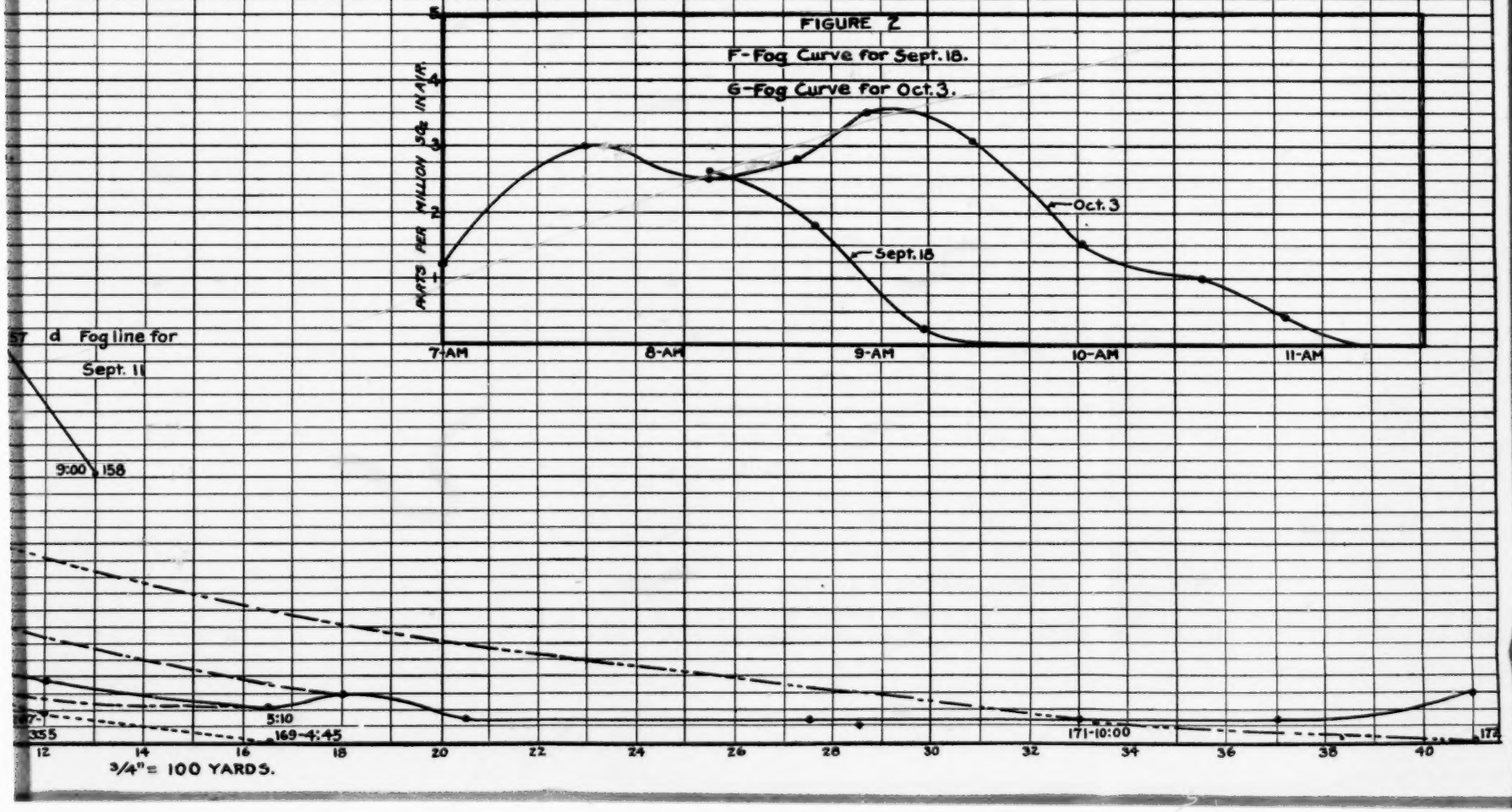
15
16

RTS PER MILLION OF SO_2 IN AIR AT VARIOUS

ISTANCES FROM SMELTER OF D. S. C. I. Co. LTD.

PLATE 5



Discussion of the Sulphur Dioxide Determinations

A diagram showing graphically the quantity of sulphur dioxide found in the air at various distances from the D. S. C. I. Co. smelter on several days and at different hours of the day will aid in the interpretation of the results of the sulphur dioxide determinations. A line drawn to represent the mean or average of all the analyses would be not only inconclusive but misleading, for the reason that the proportion of sulphur dioxide in the air at any given time and place depends largely upon the direction and velocity of the wind. The resultant of a number of determinations would vary according to the ratio of the number of samples taken in the smoke stream to the number taken outside of it. This may be illustrated by drawing the line of one of the days, Plate V, Fig. 1, so as to include several or all of the cross-marked points outside of the smoke stream. The variation would not be so great, of course, at long as at short distances.

The curve A, Fig. 1, is drawn to show the greatest amount of sulphur dioxide found at any time at the various distances. Determinations during a fog are not included in this. The low point (No. 72) at 700 yards might well be omitted as it is the record of the only experiment made at that distance, and the analyst notes that the sample was taken "in the *edge* of the smoke column."

The most important feature of the curve is that it shows the rapid diffusion of the sulphur dioxide so that at a distance less than two miles from the smelter only 0.37 parts per million remains. The larger amount, 0.76, shown in one analysis at a distance of 2¼ miles was probably due to the fact that this sample

was collected on top of a hill about one mile from the plant of the Tennessee Company.

The experiments on September 10 were made under conditions about normal—20.9 tons of sulphur dioxide escaping from the smelter, fair weather, and the wind from five to ten miles an hour. At 1650 yards the amount of sulphur dioxide found was 0.56 parts per million.

It may be worth while for illustration to describe the work of September 11 more in detail.

In the morning there was a very damp fog so dense that objects could not be seen further away than about 400 feet. A very gentle wind from the southwest had brought the smoke up the valley from the smelter early in the morning with the fog. Mr. Williamson said that he had been smelling smoke since three or four o'clock that morning. The weather report shows that the wind was variable during the morning, veering to the north and northwest and rising to nine miles an hour in the afternoon.

An analysis at the staff house at 8:00 o'clock giving 1.5 parts sulphur dioxide per million was rejected because of some irregularity; one northwest of the staff house at Captain Nolde's in the valley gave 6.14 at 8:35; and one up the valley two hundred yards further away 4.09 at 9:00 o'clock. Williamson and Overstreet then went further to the northeast, but observing the smoke drifting in the other direction (see note with No. 158), they returned and worked in the vicinity of the smelter.

In the afternoon Overstreet and McGill followed the smoke to the southeast. When sample No. 164 was taken 400 yards from the smelter at 2:30, the wind

seemed to have shifted slightly, so a second analysis was made at 2:50 directly in the smoke, and this has been used in plotting the curve. As we went further out, the sulphur dioxide decreased, and at 1650 yards none was detected.

In more than one hundred determinations made during the period from August 25 to September 13, 1915, in no case when the weather was clear, was as much as one part of sulphur dioxide per million parts of air found beyond a distance of one mile from the D. S. C. I. Co. smelter.

The amount of sulphur dioxide found during clear weather at distances greater than one thousand yards from the smelter was so small, and especially when the wind was strong and the smoke was rising, that further experiments under these conditions seemed unnecessary. But the greater percentage of sulphur dioxide found in still, foggy weather, such as prevailed on the morning of September 11—shown in the fog line *d* of Plate V, Fig. 1—called for investigation. Therefore Dr. Palmer, who began taking observations September 18, was instructed to give particular attention to this phase of the question.

On September 27th he made determinations in the fog at the staff house, finding 2.4 parts per million at 8:00 a. m. 1100 yards from the smelter; then 3.9 parts at 8:35, 3.3 at 9:05, 0.8 at 9:35, northwest of the smelter at distances of 1, 1½, 2¼, 3¼ miles, respectively.

On September 28th in the fog nearly northwest of the smelter he found 0.6 parts at 8:00 a. m., 2.05 at 8:25, 1.3 at 8:55, 1.9 at 9:35, 0.1 at 10:05 at 1, 1, 1½, 2¼ and 3⅛ miles, respectively.

Dr. Palmer says that on both of these days, at the

time when he made the last determination, "the sun had come out fairly bright and the wind had begun to blow somewhat, so that if any sulphur dioxide had been present there early in the morning, it might possibly have disappeared by the time the determinations were made." The disappearance of the sulphur dioxide as the sun comes out and the wind rises is illustrated by the experiments at the staff house on the mornings of September 18th and October 3rd, the results of which are shown graphically in Fig. 2, Plate V.

Reference to the weather report shows that the wind blew almost constantly from the southeast from the evening of September 26 to noon on the 28th, and very slowly except for three or four hours on the afternoon of the 27th. The weather conditions were such as in all probability added the effects of the smoke from the Tennessee Company plant to those of the smoke from the D. S. C. I. Co. smelter. One can not therefore reasonably hold the D. S. C. I. Co. wholly responsible for the 3.3 parts per million of sulphur dioxide in the air at a distance of 2¼ miles—the greatest amount found in our experiments that far away from the company's plant that possibly might be attributed to its smoke. Nevertheless we believe it probable that under certain weather conditions that much sulphur dioxide coming from the Ducktown Company's plant alone is sometimes present in the air at that distance.

The Least Amount of Sulphur Dioxide that Injures Vegetation

We were very desirous of determining by direct observation aided by chemical analysis the least

amount of sulphur dioxide in the smoke that would cause injury to plants under various atmospheric conditions. Many experiments have been made in Germany to ascertain this by passing sulphur dioxide over plants in glass cases; and the Selby Commission with the same end in view passed the gas over plats of barley growing in the field, varying the conditions in many ways. In both cases *sulphur dioxide mixed with air* was used. More satisfactory for the particular smoke problem would be the determination of the *amount of sulphur dioxide in the smoke* that injures the plant.

Captain Nolde lives near the west fork of Potato Creek 1100 or 1200 yards northeast of the D. S. C. I. Co. smelter. He has a great variety of flowers in his yard and garden. Leaves of some of the flowers, e. g., nasturtium, kudzu vine, and spider flower, were injured by the smoke of September 11, a sample of which taken near his residence gave an analysis 6.14 parts of sulphur dioxide per million parts of air. The injury was not severe. Many of the leaves of these plants escaped, and the leaves of many other plants were not injured at all. Under about the same conditions, several times previously, before we were prepared to make reliable analysis determining such small amounts of sulphur dioxide, somewhat severer injury had occurred to the leaves of plants at Mr. Nolde's and elsewhere in the vicinity. The extent of the injury varies with the length of time of contact, the number of applications, the state of the atmosphere, etc. Somewhat less than the amount mentioned above would probably injure the leaves of many plants in a moist atmosphere with frequent applications, or prolonged contact, and more would be required in a dry atmosphere.

Injury to Vegetation by the Ducktown Company's Smelter

In a dry atmosphere with variable wind not much injury is likely to occur more than a half mile away from the D. S. C. I. Co. smelter even with sulphur escaping in the highest amount that occurred during our investigation.

In the weather prevailing during the summer and fall of 1915, it is not probable that any visible injury was done to vegetation in Georgia by smoke from the Ducktown Company's smelter.

Within the vicinity of Isabella several times the leaves of plants were bitten as by a light frost, but the plants continued to grow and to put forth new leaves. Some leaf injury occurred at Ducktown. A large number of leaves on several trees observed was killed. Next spring the leaves will probably come out as usual; but it may be that the growth of the tree is retarded. We do not know whether the smoke came from the smelter of the Ducktown Company or the Tennessee Company. The smoke from either smelter occasionally reaches Ducktown.

Whether *within the vicinity* of the Ducktown Company's smelter, chronic or invisible injury is done to vegetation at the present time, we are not prepared to say. But having looked over the list of suits filed by individuals and corporations against the Ducktown Company and the location of the lands claimed to be damaged within the vicinity of the Ducktown Company's plant, we are of the opinion *that no visible injury of any consequence was done to vegetation on these lands by the smoke of the Ducktown Company's smelter during the period of our investigation.*

While engaged in the work incident to this investigation we devoted much time to the study of injury to plants by insects, fungi and smoke, and we have a collection of specimens showing leaf injury. We expected to discuss to some extent this phase of the subject in this report; but it seems unnecessary, and besides time is not now at our disposal to do so.

Recommendations as to Future Action

It is assumed that only recommendations would be appropriate that pertain to securing the operation of the company's plant in such a way as to guard against injury to persons and property within the vicinity and in that part of Georgia where complaint has been made.

In view of the fact that the degree of injury to vegetation by sulphur dioxide depends upon atmospheric conditions as well as upon the quantity of the gas present in the air, the inspector is of the opinion that the restriction of the company's operations during a *whole season* to an output far below its capacity is unnecessary; and that some means of regulating the quantity of sulphur escaping according to *the state of the weather* as well as by *the season of the year* might result in a larger aggregate output of manufactured products with, at the same time, less danger to vegetation within the vicinity.

The atmospheric conditions under which injury to vegetation is liable to occur are such as cause descent of the smoke while the wind is low and the humidity great. These conditions are readily recognized. The presence of sulphur dioxide is easily detected by its characteristic odor, and its quantity may be determined simply and quickly by chemical analysis. When danger to vegetation is indicated by the persistence of the above atmospheric conditions or the presence of a considerable quantity of sulphur dioxide in the air at some distance from the plant is shown by strong odor of the gas or by chem-

ical analysis, then the furnace charges and the blast should be changed so as to diminish the quantity of sulphur escaping.

It is therefore recommended

That the company be required to assign to some one the duties of watchfulness and precaution with respect to these things.

That the company be required to continue to keep a daily record such as that shown in table 2 of this report, open to inspection by the court or other authority, and also a weather record showing direction and velocity of wind at all hours of the day, and the humidity, temperature and pressure at certain intervals.

That, in ordinary conditions of the atmosphere, a total sulphur content of the gases escaping of not exceeding forty tons per day for two consecutive days during the period from May 1st to October 1st of each year be permitted, and not exceeding eighty tons per day for two consecutive days during the remaining months of the year.

That further restriction of the sulphur content of escaping gases be made for the same periods at times when unfavorable atmospheric conditions prevail.

That the present limitation of sulphur content of gases escaping to an amount not exceeding 45% of the green ore subjected to smelting be retained.

That the company be urged to enlarge the sulphuric acid plant or provide otherwise for disposing of a greater proportion of the sulphur dioxide in the gases emitted from the smelter.

That the company be urged to endeavor to lessen the leakage at the furnace and flues in order as far as possible to mitigate the unpleasant conditions about the plant due to the presence of the smoke.

Respectfully submitted,

JOHN T. MCGILL, *Inspector.*

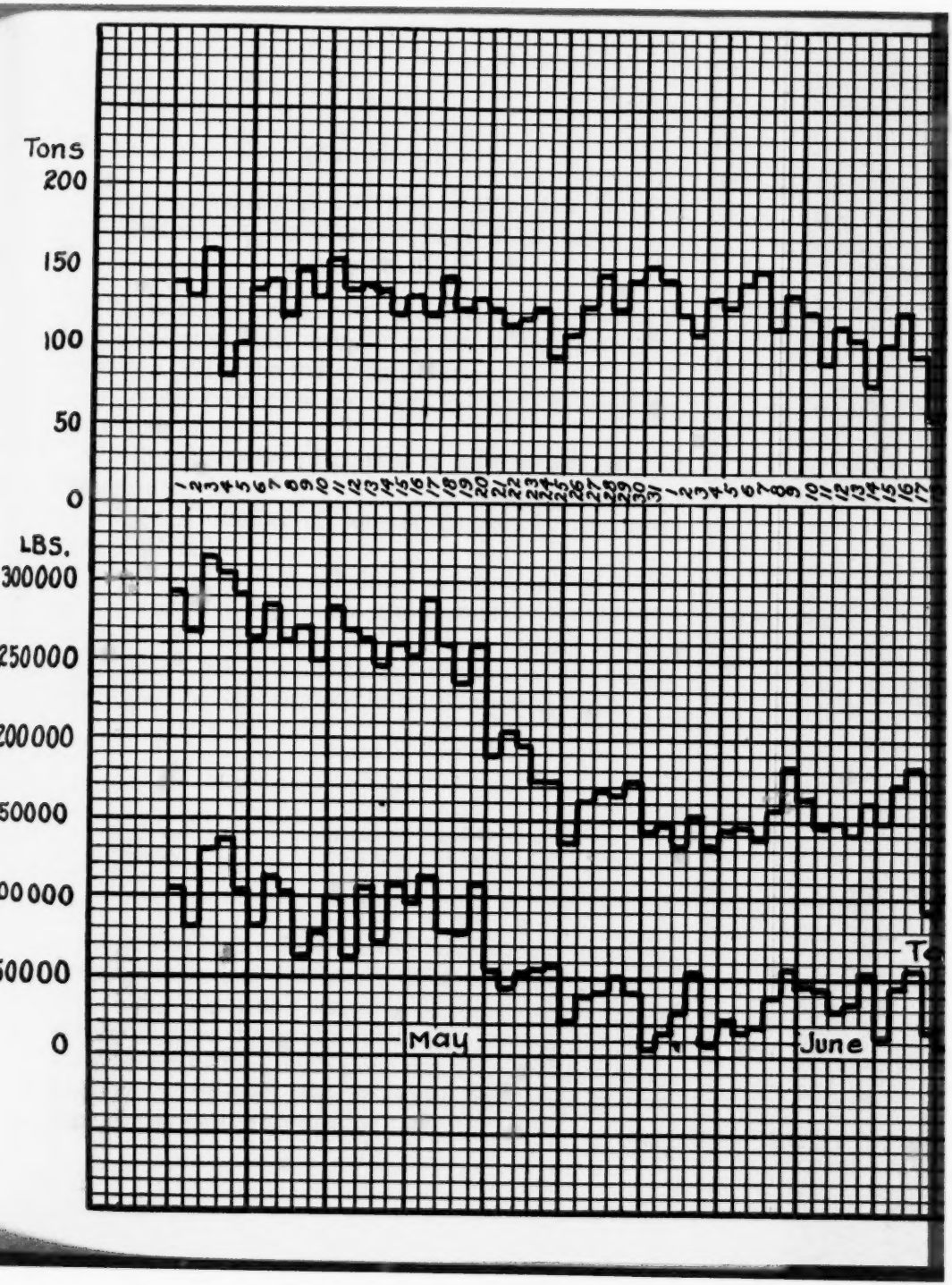

Tons
200
150
100
50
0
LBS.
300000
250000
200000
50000
00000
50000
0
May
June

PLATE 6

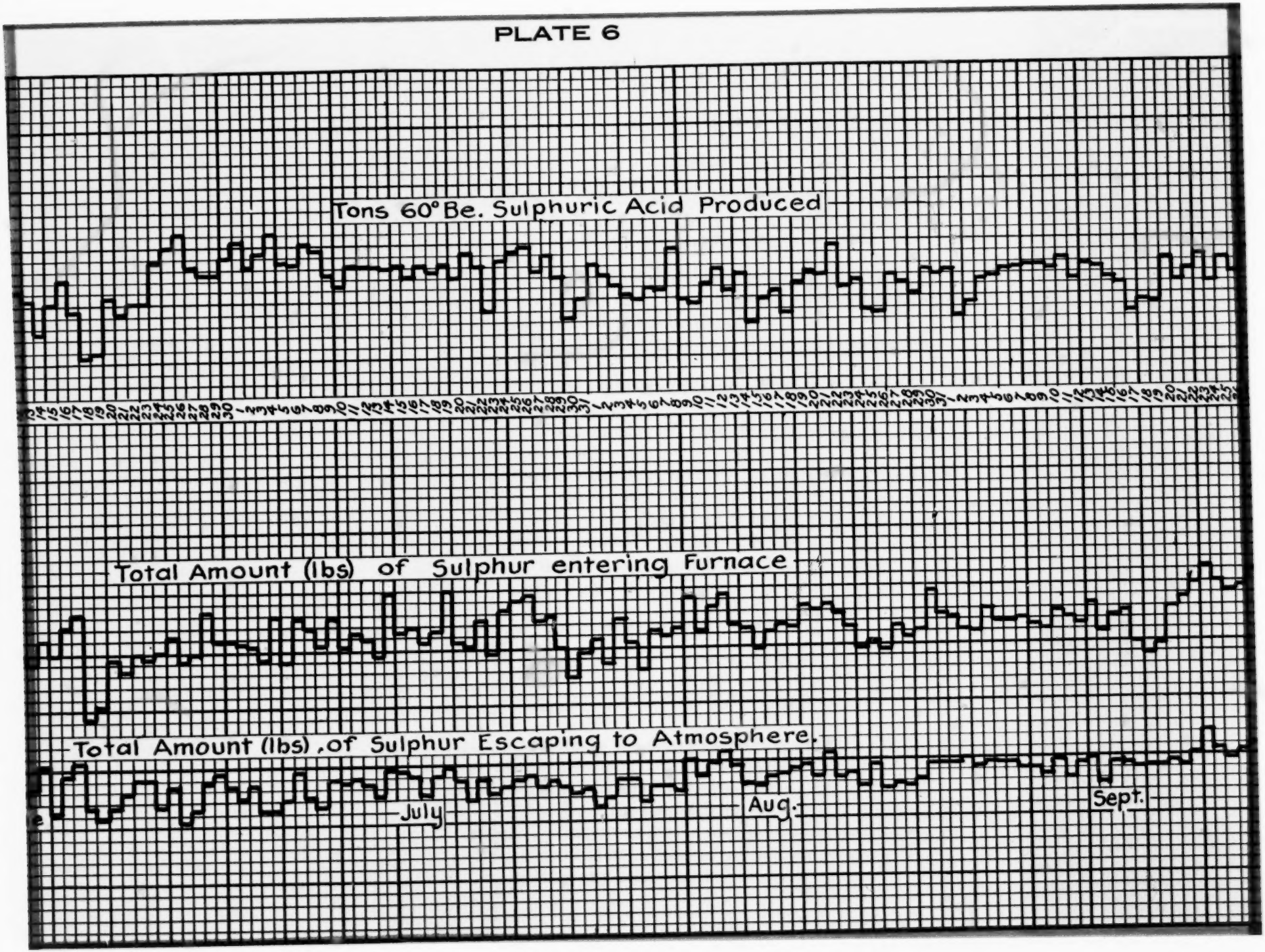
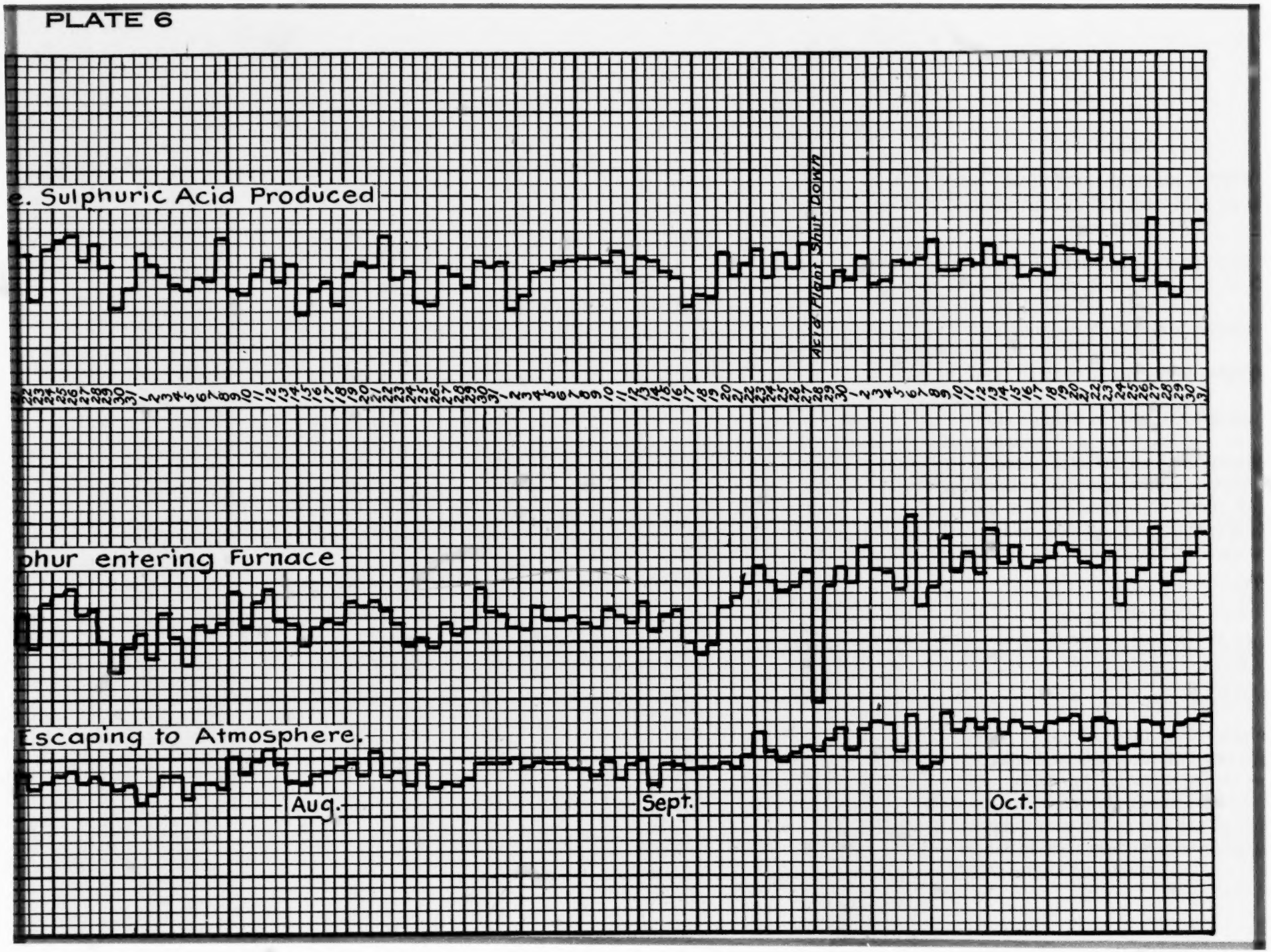

Tons 60° Be. Sulphuric Acid Produced
Total Amount (lbs) of Sulphur entering Furnace
Total Amount (lbs). of Sulphur Escaping to Atmosphere.
July
Aug.
Sept.

PLATE 6


e. Sulphuric Acid Produced
Aet of Plant Shut Down
phur entering Furnace
Escaping to Atmosphere.
Aug.
Sept.
Oct.

(Exhibit A.)

RESUME: AMOUNT OF SULPHUR OUTPUT AND ESCAPE DURING THE SIX MONTHS, MAY TO OCTOBER, INCLUSIVE, 1915

The attached print shows graphically, by means of curves plotted daily from May 1st to October 31st, inclusive, 1915, the following data:

(a) Total number of pounds of sulphur entering furnace daily.

(b) Total number of pounds of sulphur escaping to atmosphere daily.

(c) Total number of tons 60 degrees Baume' acid produced daily.

The following data, tabulated in accordance with the above notation, represents approximately the normal operations of the Ducktown Sulphur, Copper & Iron Company, Limited's smelting plant prior to the rulings prescribed by the United States Supreme Court:

TABLE I

(Covering period from May 1st to 20th)

	(a)	(b)	(c)
Maximum	315,400 lbs.	137,800 lbs.	154.00 tons
Minimum	235,400 lbs.	63,200 lbs.	80.00 tons
Mean	275,400 lbs.	100,500 lbs.	117.00 tons
Average	270,480 lbs.	96,770 lbs.	130.80 tons

According to the decree above referred to, it is ruled that the defendant Ducktown Sulphur, Copper & Iron Co., Ltd., "shall not hereafter permit to escape into the air of gases the total sulphur content of which shall exceed twenty tons during one day from April 10th to October 1st of each year or exceed forty tons in one day during any other season."

Official notice of the decree was not received until May 20th, upon which date immediate action was taken to restrict smelting operations to comply with the prescribed rulings. Reference to the attached print will show that during the five days following (May 21st to 26th, inclusive) the most conscientious effort upon the part of the entire metallurgical staff failed to reduce the escaping sulphur to within twenty tons per diem. This failure was due to a combination of several causes,—principally the inexperience of the staff in operating the furnace under such reduced capacity as was necessitated and further by the inability of the mining department to mine and apportion ores of lower sulphur content. Following these five days of experimentation, the continuous average amount of sulphur escaping to the atmosphere was maintained well below the twenty ton limit, as is best shown by the following tabulation corresponding to that shown above in Table 1:

TABLE II

(May 21st to September 19th, inclusive)

	(*a*)	(*b*)	(*c*)
Maximum	199,700 lbs.	56,500 lbs.	160.00 tons
Minimum	92,200 lbs.	1,200 lbs.	54.00 tons
Mean	145,950 lbs.	28,850 lbs.	107.00 tons
Average	159,690 lbs.	32,690 lbs.	116.66 tons

It will be noted that while the average daily escape of sulphur amounted to only 16,345 tons, nevertheless upon several occasions the amount escaping exceeded twenty tons during one day, an explanation of which, in justice to the defendant, is deemed warrantable at this time.

With a given daily smelting capacity, the total amount of sulphur entering the furnace depends pri-

marily upon the amount of sulphur contained in the ores smelted. These ores vary widely in composition from day to day, since they are mined from numerous stopes or chambers in the mines, and it is very rare that on any two consecutive days the percentage of sulphur contained in these days' shipments will be the same. The result is that the smelter is called upon to make radical adjustments in the proportioning of the charges in order to maintain even approximately a uniform amount of sulphur entering the furnace. And not only does the sulphur content vary in an uncontrollable manner, but likewise the iron and copper content of the ores. This results in a varying composition of the matte and slag products of the furnace as well as the gases leaving the furnace top and over which the smelter has only a very limited control. Nor can the metallurgist compute the exact daily output of sulphur from the furnace until the day's work is done, and all assays of the resulting furnace products have been made and careful calculations worked out. It is true that the result of these computations are employed as a basis for the following day's operations, but meanwhile it will be found that the constituents entering the furnace have again changed in composition. It is evident, therefore, that no reliable means is available to predict *exactly* that a future day's operations will produce in the amount of sulphur escaping from the furnace.

The only rational method of recovering the sulphur from escaping furnace gases thus far adaptable upon a working scale is that of converting the sulphur dioxide into sulphuric acid. The defendant's acid plant has a normal average capacity of approximately 135 tons

acid per diem when treating gases of uniform composition. Any decrease in the percentage of SO_2 results in sluggish chemical reactions in the acid making process, so that production is correspondingly reduced.

Now, the total amount of sulphur escaping to the atmosphere is equal to the difference in the amounts of actual sulphur in the dioxide leaving the smelting furnace and that recovered by the acid plant in the form of sulphuric acid. As in the case of the smelter output, so it is in computing the acid production; i. e., there is no way of predetermining the acid production.

Considering the above conditions, it is at once evident that neither the smelter nor the acid maker can predict his respective output or recovery of sulphur in such manner as to maintain a uniform escape of sulphur to the atmosphere equal to any prescribed amount, say, twenty tons per diem; nor, indeed, to approximate closely any prescribed amount.

For these reasons, the defendant has been compelled to restrict its output to an amount greatly below the prescribed amount in order to conscientiously avoid any possibility of exceeding the limiting amount, and even so, this limit is occasionally exceeded.

During the period between September 20th and October 1st, by agreement between counsel for the State of Georgia and the defendant, permission was granted Dr. McGill to conduct experimentally daily increases in the amount of sulphur escaping to the atmosphere, such total escape, however, during any one day not to exceed forty (40) tons; the object of these experiments being to note the effect of such increased amounts of sulphur upon growing vegetation prior to the natural plant maturity and the possible effects of early frosts.

These experiments are evidenced by the gradual upward trend of the curve showing total amount of sulphur escaping to the atmosphere.

The sulphur output and recovery, also acid production, during the month of October, in accordance with the prescribed 40-ton limitation, are shown in the following annotated tabulations:

TABLE III

(October 1st to 31st, inclusive)

	(*a*)	(*b*)	(*c*)
Maximum	253,500 lbs.	85,600 lbs.	159.00 tons
Minimum	175,700 lbs.	38,900 lbs.	91.00 tons
Mean	214,600 lbs.	62,250 lbs.	121.32 tons

November 3, 1915.

(Exhibit B.)

TABLE 4

Composition of Smelter Gases

1. Gas from Furnace

Test No.	*Charge*	*Date*	*Hour*	*Carbon dioxide per cent*	*Oxygen per cent*	*Carbon monoxide per cent*	*Sulphur dioxide per cent*	*Temperature of gas*
69.....	Ore	Sept. 1	11:00	6.10	1.40	1.40	7.32	.....
72.....	Ore	Sept. 1	2:45	12.44	3.60	1.20	1.56	.....
78.....	Ore	Sept. 2	2:30	11.00	1.00	0.60	5.20	.....
83.....	Ore	Sept. 3	3:30	3.30	12.00	2.40	2.30	.....
84.....	Ore	Sept. 3	4:30	8.72	2.60	1.60	5.68	.....
85.....	Ore	Sept. 6	8:00	9.40	0.60	0.80	8.00	.....

Notes

69. Taken ten minutes after charge, charging at 10-minute intervals.
72. Taken immediately after full charge was introduced.
78. Taken ten minutes after charge when charging at 12-minute intervals. Trouble with furnace operation due to chilling and low grade ores; iron scraps charged into furnace.
83. Charging on this day very irregular on account of broken scales, which made prompt weighing of charges difficult,—charging intervals ranging from four to twelve minutes. This charge made three minutes after a double charge. Scrap charged as needed to prevent chilling.
84. Sample taken one minute before charge was introduced. Old charge had been in only six minutes.
85. Charging regularly at ten-minute intervals.

2. Gas from Furnace Flue

Test No.	*Charge*	*Date*	*Hour*	*Carbon dioxide per cent*	*Oxygen per cent*	*Carbon monoxide per cent*	*Sulphur dioxide per cent*	*Temperature of gas*
33.....	Ore	Aug. 24	9:45	5.00	3.40	.....	5.40	675 C.
34.....	Ore	Aug. 24	10:15	8.80	1.40	0.80	5.40	675 C.
36.....	Ore	Aug. 24	2:00	3.56	6.20	0.20	5.04	395 C.
42.....	Ore	Aug. 25	9:30	2.69	15.40	0.00	2.11	600 C.
52.....	Ore	Aug. 26	2:30	4.95	7.00	0.00	2.05	640 C.
64.....	Matte	Aug. 30	2:00	4.39	4.40	0.00	5.61	830 C.
65.....	Matte	Aug. 30	2:00	3.39	5.90	0.00	.....	830 C.
74.....	Ore	Sept. 2	8:30	8.40	3.80	0.00	2.80	650 C.
76.....	Ore	Sept. 2	10:00	3.84	7.80	0.00	4.76	600 C.
81.....	Ore	Sept. 3	10:00	6.65	3.20	0.00	5.95	730 C.
82.....	Ore	Sept. 3	1:30	8.34	3.20	0.00	4.26	730 C.

3. Gas from Dust Chamber

Test No.	*Charge*	*Date*	*Hour*	*Carbon dioxide per cent*	*Oxygen per cent*	*Carbon monoxide per cent*	*Sulphur dioxide per cent*	*Temperature of gas*
3.....	Ore	Aug. 13	3:15	9.46	1.40	0.10	5.94	585 C.
4.....	Ore	Aug. 13	4:30	6.95	1.30	0.10	6.95	585 C.
8.....	Ore	Aug. 16	10:30	7.80	1.00	0.00	6.40	675 C.
32.....	Ore	Aug. 24	9:15	7.01	3.40	0.60	6.99	670 C.
37.....	Ore	Aug. 24	4:15	0.00	11.40	0.00	6.60	620 C.
43.....	Ore	Aug. 25	1:30	8.14	1.60	0.00	7.06	730 C.
63.....	Matte	Aug. 30	8:30	1.27	14.00	0.00	4.13	700 C.
66.....	Ore	Aug. 31	11:30	0.76	12.00	0.00	6.04	655 C.
67.....	Ore	Sept. 1	9:00	6.98	3.20	0.00	6.62	640 C.
68.....	Ore	Sept. 1	10:00	8.40	0.80	0.00	7.60	645 C.
70.....	Ore	Sept. 1	11:30	10.30	0.80	0.40	5.86	745 C.
71.....	Ore	Sept. 1	2:30	5.78	5.40	0.40	6.82	640 C.
73.....	Ore	Sept. 1	3:30	6.59	2.80	0.60	7.21	650 C.
75.....	Ore	Sept. 2	9:40	8.20	2.20	0.20	6.60	645 C.
80.....	Ore	Sept. 2	2:45	4.14	9.40	0.00	6.95	670 C.
90.....	Ore	Sept. 24	1:55	11.00	1.80	.....	5.60	670 C.
91.....	Ore	Sept. 24	3:55	8.70	2.20	0.30	6.11	570 C.

NOTES

90. Charging interval, 9 minutes. Sample taken directly after charging.
91. Charging interval, 9 minutes. Sample taken 3 minutes after charging.

4. Gas from the Main Stack

Test No.	*Charge*	*Date*	*Hour*	*Carbon dioxide per cent*	*Oxygen per cent*	*Carbon monoxide per cent*	*Sulphur dioxide per cent*	*Temperature of gas*
28.....	Matte	Aug. 23	4:00	.....	.....	.....	0.10	160 C.
30.....	Ore	Aug. 24	8:30	0.00	16.20	0.10	0.00	190 C.
31.....	Ore	Aug. 24	9:15	0.00	3.40	0.60	0.00	195 C.
35.....	Ore	Aug. 24	1:30	0.00	20.40	0.00	0.00	142 C.
40.....	Ore	Aug. 25	8:30	0.00	21.20	0.20	0.00	170 C.
46.....	Ore	Aug. 26	6:30	0.00	20.80	0.00	0.00	190 C.
53.....	Ore	Aug. 26	4:00	2.10	16.00	0.00	2.07	200 C.
63.....	Matte	Aug. 30	9:30	3.78	16.60	0.20	0.62	170 C.
86.....	Ore	Sept. 22	11:00	2.40	13.60	.....	1.16	.....
87.....	Ore	Sept. 24	8:30	2.80	11.60	.....	1.45	350 C.
88.....	Ore	Sept. 24	11:10	2.50	16.40	.....	0.72	190 C.
89.....	Ore	Oct. 8	10:00	0.10	15.90	0.00	0.38	.....

NOTES

86 and 87. Large amount of smoke coming out.
88. Fairly large amount of smoke coming out—not so much as before.
89. Not much smoke coming out.

5. Gas from Emergency Stack

Test No.	Charge	Date	Hour	Carbon dioxide per cent	Oxygen per cent	Carbon monoxide per cent	Sulphur dioxide per cent	Temperature of gas
57.....	Ore	Aug. 28	9:30	7.78	5.20	0.00	4.42	420 C.
58.....	Ore	Aug. 28	11:30	4.01	5.00	0.20	5.19	270 C.
59.....	Ore	Aug. 28	2:00	6.42	2.40	0.40	6.78	410 C.
60.....	Ore	Aug. 28	3:30	6.80	3.20	0.50	6.60	380 C.

6. Gas from the Gay Lussac Tower

Test No.	Charge	Date	Hour	Carbon dioxide per cent	Oxygen per cent	Carbon monoxide per cent	Sulphur dioxide per cent	Temperature of gas	Nitric oxide
1	Ore	Aug. 12	4:00	3.84	7.90	0.00	0.16	.....	....
2	Ore	Aug. 12	4:30	5.12	8.60	0.00	0.08	.....	....
7	Ore	Aug. 14	4:00	6.57	6.20	0.00	0.03	.....	....
9	Ore	Aug. 18	10:30	4.77	8.60	0.40	0.03	41.0	0.06
10	Ore	Aug. 18	2:00	6.15	6.60	.....	0.10	42.0	0.14
11	Ore	Aug. 18	3:00	6.30	6.60	.....	0.10	42.0	0.22
25	Ore	Aug. 21	9:30	5.33	9.80	.....	0.07	42.0	0.35
26	Ore	Aug. 21	10:30	.....	.....	.....	0.00	42.0	0.33
27	Ore	Aug. 23	7:30	.....	.....	.....	0.00	44.0	....
48	Ore	Aug. 26	9:00	18.33	5.80	0.40	0.00	41.0	0.10
49	Ore	Aug. 26	10:00	6.13	8.60	0.40	0.07	41.0	....
51	Ore	Aug. 26	1:00	4.90	8.00	0.40	0.10	42.0	0.13
54	Ore	Aug. 27	8:30	4.08	11.80	0.20	0.12	41.0	0.08
55	Ore	Aug. 27	9:30	6.26	8.60	0.00	0.14	41.0	0.39
56	Ore	Aug. 27	10:00	6.10	7.80	0.20	0,10	41.0	0.25
92	Matte	Oct. 6	11:45	3.70	9.50	0.00	0.07	.....	0.50

NOTE

92. Probably too high, as method used was not very satisfactory.

7. Vapor from the Concentration Plant

Test No.	Date	Time	Sulphur trioxide 1st Method	Sulphur trioxide 2d Method	Temperature
93.....	Oct. 8	.....	.....	0.51	.....
94.....	Oct. 10	12:45	.....	0.09	.....
95.....	Oct. 11	9:00	1.08	.....	28
96.....	Oct. 11	9:15	.....	0.68	28
97.....	Oct. 11	11:00	0.10	.....	30
98.....	Oct. 11	11:20	.....	0.05	30
99.....	Oct. 11	3:00	0.04	.....	30
100.....	Oct. 11	.....	.....	0.02	30

NOTE

Oct. 20. The plant was shut down.

Methods Used in Analysis of Gases at the Smelter

In making analysis of gases from the furnace, furnace flue, dust chamber and stacks, the *carbon dioxide, oxygen,* and *carbon monoxide* were determined by the use of Orsat's Apparatus, using potassium hydroxide (50 grams to 100 cc.) for the absorption of carbon dioxide; alkaline pyrogallol (containing 13.6 grams pyrogallol acid and 73 grams potassium hydroxide to 100 cc.) for the absorption of oxygen; alkaline or acid cuprous chloride for the absorption of carbon monoxide. *Sulphur dioxide* was determined by the Lunge-Reich Method, which consists in passing the measured gas through a known quantity of N/10 Iodine until the last drop produces a clearing of the blue color due to starch iodide. The excess is then neutralized by a few drops of Iodine necessary to reproduce the blue color. These two analyses were run simultaneously.

The per cent of sulphur dioxide was subtracted from the reading of the absorption by potassium hydroxide in the Orsat Apparatus (which represents both SO_2 and CO_2)—this gives per cent CO_2. The volumes of oxygen and carbon monoxide were read in their burettes as equal to their respective percentages since in this apparatus 100 cc. of sample are taken and measurement is before absorption.

In making analysis of the gases from the stack of the Gay Lussac tower the carbon dioxide, oxygen and carbon monoxide were determined in the Orsat Apparatus as described under "Analysis of Furnace Gases."

For sulphur dioxide the gas was passed through N/10 Iodine, a known volume of sodium thiosulphate N/10 added and the excess of permanganate titrated with N/10 ferrous sulphate.

In the method of absorption by KOH, the gas was passed through a wash bottle containing 200 cc N/10 KOH and another wash bottle containing H_2O, and the volume of the gas remaining was measured by measuring the volume of water displaced and correcting for temperature and pressure. The N/10 KOH and water were then diluted to a definite volume and an aliquot portion titrated with N/10 H_2SO_4, using methyl orange as indicator.

In the method of shaking with water, the sample of gas, generally about two liters in volume, was collected in a bottle over water by aspiration, leaving about 500 cc. of water in the bottle in which the gas was collected. This bottle was then shaken vigorously, and a definite portion of the solution diluted with N/10 KOH. The volume of gas collected was determined by measuring the volume of water displaced and correcting for temperature and pressure.

It is noted that the results by absorption in KOH are much higher than the results by absorption in H_2O, probably indicating incomplete absorption in the latter case.

Financial Statement

Receipts		$1,750.00
Disbursements—		
Travel—Seven trips to Isabella, one to Atlanta, one to Washington, one to St. Louis, Mo., and Hillsboro, Ill.	$306.17	
Board	61.58	
Office expenses	12.67	
Supplies and transportation for investigations	507.39	
Salary of assistants	755.00	
Assistance in the field	118.97	
Labor	109.80	
Report	212.00	
		$2,083.58
Deficit		$ 333.58
Credit D. S. C. I	$ 10.00	
on R. R. tickets	23.40	
		33.40
Total deficit		$ 300.18

ACKNOWLEDGMENT

I wish to acknowledge my indebtedness first of all to Mr. Charles S. Williamson, Jr., Associate Professor of Industrial Chemistry in Tulane University. Most of the chemical work was done by him, and his counsel and coöperation were, I might say, almost indispensable. Mr. J. B. Overstreet, a graduate of the Alabama Polytechnic College, was prompt and efficient in the work assigned him. Dr. Howard E. Palmer, of the Bureau of Chemistry, Washington, D. C., whom the Chief of the Bureau, Dr. Carl Alsberg, kindly gave leave of absence for a month, did excellent service in continuing the work through the latter part of September and the first week in October.

I wish to express my thanks to Mr. C. W. Renwick, Manager, and Mr. W. F. Lamoreaux, Assistant Manager, for their kind treatment of myself and associates; and to say that they afforded us every facility for the investigation and ever expressed the desire that it be made as thorough as possible.

To Professor Samuel Bain, of the University of Tennessee, I am indebted for literature relating to injury to plants by insects, fungi, and sulphur dioxide, and to officials of the Bureau of Mines for proofs of the method used by the Selby Commission for the determination of sulphur dioxide.

JOHN T. MCGILL.

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No. 1, ORIGINAL

IN THE

Supreme Court of the United States

OCTOBER TERM, 1915

THE STATE OF GEORGIA, Plaintiff,

vs.

THE TENNESSEE COPPER COMPANY AND THE DUCKTOWN SULPHUR, COPPER & IRON COMPANY, LIMITED, Defendants

In Equity

APPLICATION OF DEFENDANT DUCKTOWN SULPHUR, COPPER & IRON COMPANY FOR A FINAL DECREE DISMISSING THE ORIGINAL BILL AS TO IT AND BRIEF AND ARGUMENT IN SUPPORT THEREOF

W. B. MILLER,
J. A. FOWLER,
Solicitors for Ducktown Sulphur, Copper & Iron Company, Limited.

PUBLIC PRINTING CO. KNOXVILLE

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APPLICATION OF DEFENDANT DUCKTOWN SULPHUR, COPPER & IRON COMPANY FOR A FINAL DECREE DISMISSING THE ORIGINAL BILL AS TO IT

To the Honorable The Supreme Court of the United States:

This defendant respectfully shows to the Court:

I.

At the October Term, 1914, after a hearing had been had on a motion of plaintiff for a final injunction and on application of the defendant Ducktown Sulphur, Copper & Iron Company, Limited, for permission to show changed conditions and for a final decree dismissing the original

bill as to it, the following order was entered by the Court:

"On consideration of the motion of complainant for final injunction, the application of defendant Ducktown Sulphur, Copper & Iron Company, Limited, to show changed conditions, the proof submitted thereon, and of the argument of counsel thereupon had, and the Court being of opinion that by reducing the amount of sulphur discharged into the air said defendant probably can operate its plant without subjecting the territory of Georgia to serious danger of immediate injury, and deeming it desirable to be more fully informed concerning the true conditions and results which may be obtained by subduing the noxious gases discharged.

"IT IS ACCORDINGLY ordered, adjudged and decreed:

"(1) That the defendant Ducktown Sulphur, Copper & Iron Company, Limited, shall hereafter keep daily records showing fully and in detail the course and result of its operations.

"(2) That Dr. John T. McGill, of Vanderbilt University, Nashville, Tennessee, is hereby appointed inspector to observe the operations of said defendant's plant and works. He shall be given by it at all times free and full access to its books, records and premises, and during the next six months he shall make frequent and careful observations—at least once each fortnight—of the conditions of the plant and works, the manner of their operation, the quantity and character of smoke emitted therefrom, and the resulting effect upon vegetation within the vicinity and in the State of Georgia. At the end of that time he shall make a full report of his observations, accom-

panied by recommendations as to appropriate future action. To cover necessary cost and expenses incident to these services and the reasonable compensation of the Inspector, the defendant Ducktown Sulphur, Copper & Iron Company, Limited, is hereby directed to deposit with the Clerk of this Court, within ten days, the sum of five thousand dollars. Of this sum not exceeding two thousand dollars shall be paid from time to time, prior to October 12th next, by the Clerk to the Inspector, upon his written application, to cover costs, expenses, and on account of his services, etc.

"(3) That said defendant hereafter shall not permit the escape into the air from its works of fumes carrying more than 45% of the sulphur contained in the green ore subjected to smelting.

"(4) That it shall not hereafter permit the escape into the air of gases the total sulphur content on which shall exceed twenty tons during one day from April 10th to October 1st of each year or exceed forty tons in one day during any other season.

"(5) That the cause will be retained upon the docket for such further action as may appear proper, and either party may at any time hereafter apply for relief as it may be advised."

II.

Dr. McGill accepted said appointment and has made, most faithfully and carefully, the observations specified in said order, every possible facility and assistance being given him by this defendant; and on January 1, 1916, he filed his report setting forth in detail the facts ascertained by him, to which report reference is here specially made.

III.

This defendant insists that the facts so found and reported are in complete accord with its contentions insisted on before the Court on the hearing at the October term, 1914, in that they show that since the hearing in 1907 this defendant has expended much in excess of $600,000 in the construction of an acid plant and other devices to remove the sulphur from the fumes created by the smelting of its ores; that such efforts have been highly successful, and that on an average less than forty per cent of the sulphur in the green ore smelted now escapes into the atmosphere; that both the operation of the plant in respect to said sulphur fumes and the condition of the vegetation in the surrounding vicinity have entirely changed since the said hearing in 1907; that there is no probability that any damage—and certainly no possibility that any material damage—is now being done, or for a number of years has been done, to crops or forests or to any form of vegetation in the State of Georgia by sulphur fumes escaping from this defendant's plant; and that this defendant has acted in the best of faith in its efforts to prevent the possibility of any injury being done to vegetation in the State of Georgia, and still continues such efforts, and there is no fact stated in the report of the Inspector, nor is there any reliable evidence on file, which tends to show that this defendant's action has not been prompted by an honest desire to relieve the situation existing when the first hearing was had, or that it will ever permit a sufficient amount of sulphur to escape to create a nuisance in the State of Georgia.

IV.

The defendant Ducktown Sulphur, Copper & Iron Com-

pany, Limited, therefore, prays that this cause be again considered by this Honorable Court upon the report of said Inspector and the evidence now on file, and that a final decree be entered, dismissing the cause as to it.

In support of this application, defendant presents to the Court herewith a brief, citing the particular parts of said report, and certain items of evidence in the record, and the legal authorities upon which it specially relies.

DUCKTOWN SULPHUR, COPPER & IRON CO., Ltd.,

By J. A. FOWLER, Solicitor.

W. B. MILLER,

J. A. FOWLER,

Solicitors.

Service of notice that the foregoing application will be made on February 28, 1916, was acknowledged on February 15, 1916.

IN THE

Supreme Court of the United States

OCTOBER TERM, 1915

THE STATE OF GEORGIA

vs.

THE TENNESSEE COPPER COMPANY AND THE DUCKTOWN SULPHUR, COPPER & IRON COMPANY, LIMITED

BRIEF AND ARGUMENT IN SUPPORT OF APPLICATION OF THE DUCKTOWN SULPHUR, COPPER & IRON COMPANY, LIMITED, FOR A FINAL DECREE DISMISSING THE ORIGINAL BILL AS TO IT

I.

REPORT OF THE SPECIAL COMMISSIONER

Those facts stated in the report of the Special Commissioner which are here specially relied on can best be understood by briefly summarizing the report with quotations of some of the principal findings.

1st. **Preliminary matters contained in report.**

There is first given an analysis of the ores taken from the several mines operated by the defendant Company

(p. 6), and then its several plants are described (pp. 7-8) and also the operations of same (p. 9). Only one furnace is operated at a time, except for a short time when a change is made from one furnace to the other (p. 10). The furnace products are the matte, the slag and the smoke, mixed with the residuary of the blast. Low grade matte containing from 12 to 20% of copper and from 22 to 24.5% of sulphur is separated from the remaining matte and is subsequently broken up and again smelted to produce high grade matte, which contains from 40 to 47% of copper and about 23.5% of sulphur (p. 10). The smoke contains flue dust, fume and gas. The flue dust consists of particles thrown out of the furnace by the force of the blast. The fume consists of vapors of substances formed in the combustion. A variable portion of the smoke escapes from the furnace by leakage around the lid and during the charge. The remainder passes from the furnace into the furnace flue, where most of the flue dust and a portion of the fume are deposited, and then into a large brick dust chamber. From this the fume and gasses are distributed (1) to the sulphuric acid plant by way of a circular tower and long flue; (2) to the reduction plant by way of the bag house; and (3) to the main stack.

Then follows a description of the course the gases take which enter the sulphuric acid plant, and also of the manner in which the smoke that leaves the dust chamber for the reduction plant is treated (pp. 11-12).

A daily record of the material treated and the amount of copper, iron and sulphur contained therein was kept by the Company from May 1st, 1915, to December 1st, and these records of June 6th and September 11th presented as samples are set forth on page 15.

Because of some analysis of slag made by Professor Pratt of N. B. Pratt Company, of Atlanta, and W. E. Grainger, of Knoxville, the Company's estimates of sulphur escaping daily in the gases were thought to be too low to the extent of three tons per day from June 1st to August 30th, and 1.2 tons after that date (pp. 16-17). The analysis of other material by the Company were found to be about correct.

On page 19 appears a table showing the green ore smelted, the sulphur in the green ore, acid made, sulphur in acid, per cent of sulphur recovered, sulphur escaping and per cent of sulphur escaping during the months from June to November, inclusive, from which it appears that reckoning the average amount of sulphur escaping per month, the limit of twenty tons was not exceeded in the first four months or the limit of forty tons the last two months, but it is said that if single days be considered the limit of twenty days was exceeded twenty-eight times in the hundred and eleven days from June 1st to September 20th, and the forty ton limit six times in the ninety-two days it was allowable from September 20th to December 1st (p. 19).

An explanation of why this limit was exceeded was submitted by the Company accompanied by a plat showing total number of pounds of sulphur entering furnace daily, total number of pounds of sulphur escaping in the atmosphere daily and total number of tons of acid, Baumé, produced daily, which constitutes Exhibit "A" to the report; and comments thereon corroborating the Company's statement appear on pages 17 and 18.

2nd. **Provision Limiting Escaping Sulphur to 45% of Sulphur in Green Ore.**

With reference to that part of the decree which reads "That said defendant shall not hereafter permit the escape into the air from its works of fumes carrying more than forty-five per cent of the sulphur contained in the green ore subjected to smelting," it is said that it was evidently not intended to apply to every single day, for on days when the furnace is run to make high grade matte the green ore constitutes but a small proportion of the charge, and the sulphur escaping, being derived largely from the low grade matte of the charge may, without exceeding the twenty or forty ton limit in quantity, be much above the forty-five per cent of the green ore used in smelting. In making the estimate by the months, it is found that the daily average for the first four months was 29.46%; for the whole six months 35.53%; for the last two months 44.48%; and for the month of November, 48.78%. It is explained, however, that there were only two days in November during which the forty ton limit was passed, and they were the 10th and 21st; and on the 10th the Company was changing furnaces, in doing which it was necessary to charge into the blowing out furnace a larger proportion of coke than usual, which increased the percentage of carbon dioxide in the furnace gases, thus retarding the formation of acid, and allowing more of the sulphur to escape into the air. The total amount of material charged into the furnace on that day was the largest of any day in the whole six months, and yet the amount of sulphuric acid made was only 108 tons (p. 20). (The capacity of the plant is 160 tons of sixty degrees Baumé acid, and the usual average is about 135 tons (p. 7).

3rd. **Analysis of Flue Dust and Gases.**

An analysis of flue dust is then given, and also of samples of gasses taken from (1) the furnace; (2) the furnace flue; (3) the dust chamber; (4) the main stack; (5) the emergency stack; (6) the Gay Lussac tower; (7) the sulphuric acid concentration plant; (8) the reduction plant. A tabular statement of these analyses appears on pages 66 to 68 (pp. 21-24).

The analyses of six samples taken from the furnace shows, on an average, carbon dioxide 8.50%, sulphur dioxide 4.40%; of ten samples taken from the furnace flue shows carbon dioxide 5.56%, sulphur dioxide 4.40%; of seventeen from the dust chamber, carbon dioxide 6.56%, sulphur dioxide 6.10%; of four from the emergency stack, carbon dioxide 6.03%, sulphur dioxide 5.77%; while sixteen analyses of the gas taken from the exit of the Gay Lussac tower (after it has passed through the acid chamber) give an average of carbon dioxide 6.66%, and sulphur dioxide .27%, which shows **"that the sulphur dioxide has nearly all been eliminated from the furnace gas in making sulphuric acid"** (p. 25).

4th. **Ducktown Basin and History of Smelting Therein.**

The Ducktown Basin is approximately an ellipse, with major axis about sixteen miles long and minor axis of half that length, the course of same being about south twenty degrees west and north twenty degrees east. Its elevation is from sixteen to seventeen hundred feet. It is cut by streams into narrow valleys a hundred and fifty feet lower and bordered by ridges and mountains from three hundred to fifteen hundred feet higher. About one-

third of the Basin lies in Tennessee and the remainder in Georgia. Four creeks pass through the Basin and enter Ocoee River (or Toccoa River, in Georgia) (p. 26).

Some ten or twelve square miles of the Basin which lies north of the Ocoee River is devoid of vegetation, with the exception of sage grass and wild smilax and yards and gardens cultivated by a few of the residents, and several peach orchards.

Bordering this desert region is one covered with sage grass and vines and a few stunted shrubs and small trees, often with dead tops; some places numerous young maples are seen, but they are likely to be destroyed by fires starting in the sage grass in the fall or winter. Along the streams other grasses are found, and there is a more thrifty growth of trees on slopes and in hollows and in coves somewhat sheltered from winds blowing from the central area. Dogwood, sourwoods and black gums constitute the principal growth in such places. This territory extends on the south from one to two miles into Georgia.

Beyond this border the country for some distance is not heavily wooded. Most of the larger trees were cut down years ago and sold to the Copper Company. The forest growth in a large part of this region does not appear thrifty. Trees with dead or dying tops seem more numerous than is usually seen under similar soil and climatic conditions elsewhere.

"Generally speaking, the area to which this description applies extends to the rim of the Ducktown Basin and perhaps even farther in some directions" (p. 27).

5th. **History of Copper Smelting in the Ducktown Basin.**

Before the organization of the Ducktown Company the copper ores were smelted in charcoal reduction furnaces or worked by the leaching and precipitation process. The method used by the Ducktown Company for ten years after beginning operations in 1893 consisted in first roasting the ore in heaps between layers of wood in the open air, and then smelting the roasted ore in a charcoal reduction furnace. The Pittsburgh Company adopted the same method in 1894, and this was continued by its successor, the Tennessee Copper Company. These roast sheds occupied acres of ground, and the wood required for firing them in the course of ten years practically exhausted the timber in the forest for miles around. The smoke from the burning wood and roasting ore formed a cloud so dense, it is said, that it was often difficult to find one's was through it. Its area of destruction in the period of ten years was probably coterminous with the barren central zone described.

In 1903 both companies began to prepare for smelting the green ore by the pyritic or blast furnace process, and by the end of 1905 the open air roasting had ceased. This eliminated the wood smoke and limited the escape of the smoke to the stack and leakage from the furnace, but the amount of sulphur escaping into the air was but slightly, if any, less than in treating the same amount of ore by roasting and charcoal smelting.

On page 29 appears a table which shows the tons of ore smelted by the defendant company, and the tons of sulphur escaping from its furnaces during the years 1901 to 1908, inclusive. **It appears from this table that the relative**

amounts of sulphur emitted daily by the Ducktown Company and by the Tennessee Company during that period are as follows:

	Total Emitted (Tons)	Ducktown Co.	Tennessee Co.
1901	90	60	30
1902	184	70	114
1903	202.9	50	152.9
1904	216.9	75.9	141
1905	259.6	115	144.6
1906	303.5	147	156.5
1907	286.6	94	192.6
1908	303	70	233

(p. 29)

NOTE—It will thus be seen that during the year 1908 the Tennessee Company emitted more than three times as much sulphur into the air as the Ducktown Company, and more than twice as much during the preceding year.

After the change to the pyritic method the scale of operations was largely increased, and complaint was made by the citizens of both Tennessee and Georgia.

In 1906 the Tennessee Copper Company erected a stack 325 feet high; that is, about 175 feet higher than the general level of the higher ground of the Ducktown Basin. This did not stop the complaints of the citizens, and this action was instituted.

The main stack of the Ducktown Company rises only 90 feet above the smelter yard. Its top is a little below the summit of the hills nearby, and 185 feet below that of the top of the Tennessee stack (p. 31).

6th. **Efforts of the Ducktown Company to utilize the sulphur dioxide of the smoke.**

There is much to show that the Ducktown Company

acted in good faith in an endeavor to install appliances to eliminate the fumes and gases complained of. Preliminary experiments were made in 1905 and 1906 with the contact method of manufacturing sulphuric acid. A ten ton plant was erected and the process tried in 1907 and 1908, at a cost of $60,000.00. The method was found to be impracticable with the gases treated, and it was adandoned. The chamber acid plant now used was erected in 1908 and 1909 at a cost of more than $500,000.00. It was put into operation in June, 1909. Improvements and enlargements up to the present time have added $100,000.00 to the costs. In the endeavor to convert a greater percentage of the ore into sulphuric acid a McDougall roaster was erected and tried in 1913 and 1914, at a cost of $20,000.00. It is no longer in use. At the same time the floatation method now used successfully with zinc ores was tried, at a cost of $10,000.00. This plant was destroyed by fire in September.

An experiment which has for its object the utilization of the sulphur dioxide of the fumes in the manufacture of elemental sulphur is now being tested. This process was patented by Mr. Lamoreaux and Mr. Renwick and was tried on a small scale in 1914. In the summer and fall of 1915 a plant was built which was calculated to make three tons of sulphur a day. The cost of this plant was $30,000.00, and it has been running almost continually since the last of October (pp. 32-33).

7th. **Improved Conditions since 1907.**

Conditions have improved since 1907. The amount of ore then smelted by the Company was as great as now or greater, but all the sulphur gases then escaped into the atmosphere, while now **more than fifty per cent** of it is utilized in the manufacture of sulphuric acid (p. 33).

8th. **How Vegetation May be Injured.**

Plants may be injured either by impoverishing or poisoning the soil, or by attacking the leaves. It is found that no injury results to vegetation through the soil from the presence of these fumes (pp. 34-35). Sulphur dioxide is the constituent of sulphuretted fumes most injurious to vegetation, and the question is narrowed to injury by sulphur dioxide in the smoke (p. 35).

The solution of the problem is complicated by the fact that there are two smelters in this region, and that during the period of this investigation the smoke from either furnace has probably at some time reached every locality in the Ducktown Basin.

9th. **Observing Station and Operations Therefrom.**

A small tower was erected on an observing station on a hill at an elevation of 1785 feet, 600 yards, 4 degrees west of south from the Company's smelter and 2.3 miles from the Tennessee Company smelter. This station was equipped with proper appliances for observation. From this station the plants of the Ducktown and Tennessee Companies were both visible, as was also practically the whole Ducktown Basin to the rim of the mountains that surround it. The method adopted for determining the amount of sulphur dioxide was that used by the Selby Smelter Commission in an investigation carried on in Solano County, California (pp. 38-39). A full description of the operations from this station is given. It was "decided to determine the sulphur dioxide in as many samples as possible collected in the region between Isabella and Georgia at times when the wind

was blowing the smoke from the Ducktown Company's smelter toward Georgia. This would eliminate the smoke from the Tennessee Company's plant as a factor, provided the samples were not taken too soon after the wind had changed from a southerly to a northerly direction. A sufficient number of such analyses made at different distances from the source of smoke and under various conditions of wind and weather and sulphur dioxide output of the smelter it was thought ought to supply the necessary data for calculating the rate of diffusion and the degree of dilution of the gas at points within the vicinity and in the State of Georgia." (p. 40).

10th. Course of smoke from Ducktown smelter.

The Ducktown Company's smelter is situated at the junction of the narrow valleys of Potato Creek and Stewardtown Creek. The smoke stack does not rise to the level of the tops of the hills nearby, but ordinarily when the smoke is issuing freely from the stack it rises above the hills and moves over them without much obstruction. The smoke escaping from the top of the furnace, which much of the time during small output seems the greater quantity, comes out of the smelter shed more diffused than the stack smoke, and has a tendency to drift along the valley running nearest the direction the wind is moving, that is northeast up Potato Creek, southeast up Stewardtown Creek, southwest down Potato Creek. In certain conditions of the atmosphere, for example, during a fog, this is true of the smoke from the stack also.

"These statements must not be construed to imply that the smoke may flow down the narrow, crooked valley of Potato Creek and by reason of this channel be capable

of doing injury to vegetation across the Ocoee River in Tennessee and Georgia" (p. 42).

11th. Table of readings.

A table is given which shows a hundred and seventy-four readings made on twenty different days, beginning August 25th and extending to October 3rd (pp. 43-52). This table is very important, and special attention will be hereinafter called to certain facts conclusively proven thereby.

12th. Comments in the report upon these observations.

The comments of the Special Commissioner upon these observations and his deductions therefrom are all important, and hence are quoted in full as follows:

"Discussion of the Sulphur Dioxide Determinations

"A diagram showing graphically the quantity of sulphur dioxide found in the air at various distances from the D. S. C. I. Co. smelter on several days and at different hours of the day will aid in the interpretation of the results of the sulphur dioxide determinations. A line drawn to represent the mean or average of all the analyses would be not only inconclusive but misleading, for the reason that the proportion of sulphur dioxide in the air at any given time and place depends largely upon the direction and velocity of the wind. The resultant of a number of determinations would vary according to the ratio of the number of samples taken in the smoke stream to the number taken outside of it. This may be illustrated by drawing the line of one of the days, PlateV, Fig.

1, so as to include several or all of the cross marked points outside of the smoke stream. The variation would not be so great, of course, at long as at short distances.

"The curve A, Fig. 1, is drawn to show the greatest amount of sulphur dioxide found at any time at the various distances. Determinations during a fog are not included in this. The low point (No. 72) at 700 yards might well be omitted as it is the record of the only experiment made at that distance, and the analyst notes that the same was taken 'in the edge of the smoke column.'

"The most important feature of the curve is that it shows the rapid diffusion of the sulphur dioxide so that at a distance less than two miles from the smelter only 0.37 parts per millon remains. The larger amount, 0.76, shown in one analysis at a distance of 2¼ miles was probably due to the fact that this sample was collected on top of a hill about one mile from the plant of the Tennessee Company.

"The experiments on September 10 were made under conditions about normal—20.9 tons of sulphur dioxide escaping from the smelter, fair weather, and the wind from five to ten miles an hour. At 1650 yards the amount of sulphur dioxide found was 0.56 parts per million.

"It may be worth while for illustration to describe the work of September 11 more in detail.

"In the morning there was a very damp fog, so dense, that objects could not be seen further away than about 400 feet. A very gentle wind from the southwest had brought the smoke up the valley from the smelter early in the morning with the fog. Mr. Williamson said that he had been smelling smoke since three or four o'clock

that morning. The weather report shows that the wind was variable during the morning, veering to the north and the northwest and rising to nine miles an hour in the afternoon.

"An analysis at the staff house at 8:00 o'clock giving 1.5 parts sulphur dioxide per million was rejected because of some irregularity; one northwest of the staff house at Captain Nolde's in the valley gave 6.14 at 8:35; and one up the valley two hundred yards further away 4.09 at 9:00 o'clock. Williamson and Overstreet then went further to the northeast, but observing the smoke drifting in the other direction (see note with No. 158), they returned and worked in the vicinity of the smelter.

"In the afternoon Overstreet and McGill followed the smoke to the Southeast. When sample No. 164 was taken 400 yards from the smelter at 2:30, the wind seemed to have shifted slightly, so a second analysis was made at 2:50 directly in the smoke, and this has been used in plotting the curve. As we went further out, the sulphur dioxide decreased, and at 1650 yards none was detected.

"In more than one hundred determinations made during the period from August 25 to September 13, 1915, in no case where the weather was clear, was so much as one part of sulphur dioxide per million parts of air found beyond a distance of one mile from the D. S. C. I. Co. smelter.

"The amount of sulphur dioxide found during clear weather at distances greater than one thousand yards from the smelter was so small, and especially when the wind was strong and the smoke was rising, that further experiments under these conditions seemed unnecessary. But the greater

percentage of sulphur dioxide found in still, foggy weather, such as prevailed on the morning of September 11—shown in the fog line **d** of Plate V, Fig. 1—called for investigation. Therefore, Dr. Palmer, who began taking observations September 18, was instructed to give particular attention to this phase of the question.

"On September 27th he made determinations in the fog at the staff house, finding 2.4 parts per million at 8:00 a. m. 1100 yards from the smelter; then 3.9 parts at 8:35, 3.3 at 9:05, 0.8 at 9:35, northwest of the smelter at distances of 1, 1½, 2¼, 3¼ miles, respectively.

"On September 28th in the fog nearly northwest of the smelter he found 0.6 parts at 8:00 a. m., 2.05 at 8:25, 1.3 at 8:55, 1.09 at 9:35, 0.1 at 10:05, at 1, 1½, 2¼, and 3⅛ miles, respectively.

"Dr. Palmer says that on both of these days, at the time when he made the last determination, 'the sun had come out fairly bright and the wind had begun to blow somewhat, so that if any sulphur dioxide had been present there early in the morning, it might possibly have disappeared by the time the determinations were made.' The disappearance of the sulphur dioxide as the sun comes out and the wind rises is illustrated by the experiments at the staff house on the mornings of September 18th and October 3rd, the results of which are shown graphically in Fig. 2, Plate V.

"Reference to the weather report shows that the wind blew almost constantly from the southeast from the evening of September 26 to noon on the 28th, and very slowly except for three or four hours on the afternoon of the 27th. The weather conditions were such as in all probability added the effects of the smoke from the Tennessee Company plant to those of the smoke from the D. S. C. I.

Co. smelter. One cannot, therefore, reasonably hold the D. S. C. I. Co. wholly responsible for the 3.3 parts per million of sulphur dioxide in the air at a distance of 2¼ miles—the greatest amount found in our experiments that far away from the Company's plant that possibly might be attributed to its smoke. Nevertheless, we believe it probable that under certain weather conditions that much sulphur dioxide coming from the Ducktown Company's plant alone is sometimes present in the air at that distance.

"The Least Amount of Sulphur Dioxide that Injures Vegetation

"We were very desirous of determining by direct observation aided by chemical analysis the least amount of sulphur dioxide in the smoke that would cause injury to plants under various atmospheric conditions. Many experiments have been made in Germany to ascertain this by passing sulphur dioxide over plants in glass cases; and the Selby Commission with the same end in view passed the gas over plats of barley growing in the field, varying the conditions in many ways. In both cases **sulphur dioxide mixed with air** was used. More satisfactory for the particular smoke problem would be the determination of the **amount of sulphur dioxide in the smoke** that injures the plant.

"Captain Nolde lives near the west fork of Potato Creek 1,100 or 1,200 yards northeast of the D. S. C. I. Co. smelter. He has a great variety of flowers in his yard and garden. Leaves of some of the flowers, e. g., nasturtium, kudzu vine, and spider flower, were injured by the smoke of September 11, a sample of which taken near his residence, gave an analysis 6.14 parts of sulphur

dioxide per million parts of air. The injury was not severe. Many of the leaves of these plants escaped, and the leaves of many other plants were not injured at all. Under about the same conditions, several times previously, before we were prepared to make reliable analysis determining such small amounts of sulphur dioxide, somewhat severer injury had occurred to the leaves of plants at Mr. Nolde's and elsewhere in the vicinity. The extent of the injury varies with the length of time of contact, the number of applications, the state of the atmosphere, etc. Somewhat less than the amount mentioned above would probably injure the leaves of many plants in a moist atmosphere with frequent applications, or prolonged contact, and more would be required in a dry atmosphere.

"Injury to Vegetation by the Ducktown Company's Smelter

"In a dry atmosphere with variable wind not much injury is likely to occur more than a half mile away from the D. S. C. I. Co. smelter even with sulphur escaping in the highest amount that occurred during our investigation.

"In the weather prevailing during the summer and fall of 1915, it is not probable that any visible injury was done to vegetation in Georgia by smoke from the Ducktown Company's smelter.

"Within the vicinity of Isabella several times the leaves of plants were bitten as by a light frost, but the plants continued to grow and put forth new leaves. Some leaf injury occurred at Ducktown. A large number of leaves on several trees observed was killed. Next spring the leaves will probably come out as usual; but it may be that the growth of the tree is retarded. We do not know whether the smoke came from the smelter of

the Ducktown Company or the Tennessee Company. The smoke from either smelter occasionally reaches Ducktown.

"Whether **within the vicinity** of the Ducktown Company's smelter, chronic or invisible injury is done to vegetation at the present time, we are not prepared to say. But having looked over the list of suits filed by individuals and corporations against the Ducktown Company and the location of the lands claimed to be damaged within the vicinity of the Ducktown Company's plant, we are of opinion **that no visible injury of any consequence was due to vegetation on these lands by the smoke of the Ducktown Company's smelter during the period of our investigation.**" (Report pp. 53-58).

II.

This report fully confirms the contention of this defendant at the last hearing, based on the evidence in the record, and shows conclusively that it is altogether improbable that crops or forests in Georgia have been for the last few years, or will ever be in the future, injured by fumes escaping from defendant's plant.

In support of this proposition, special attention is called to certain facts appearing in the report and in the evidence on file, though they can add but little to the comments made by the Special Commissioner based upon his observations and experimentations—

1st. **Facts shown by table of observations on pages 45 to 52 of the report.**

A careful study of this table is important. The distance of the defendant's plant from the Georgia line is 2.6 miles, or 4,576 yards (p. 30). It will be observed that

nearly all the tests were made much within that distance. In fact, by far the majority were made within less than half a mile, and many of them within a few yards of the furnace. A list of those made more than one mile from the furnace is as follows:

Date	Test No.	Parts per million	Distance
Aug 28th	12	.37	1,800 yards
Aug. 30th	26	.38	2,000 yards
" "	33	.37	3,700 yards
" "	34	.37	3,700 yards
" "	35	.19	3,700 yards
" "	36	.19	3,700 yards
" "	37	.37	2,475 yards
" "	38	.37	2,775 yards
" "	39	.00	2,775 yards

With reference to experiments made August 30th, it is said in a note that the smoke seemed to stick to the ground, although appearing in light clouds, and small percentage of sulphur dioxide was found at a distance of more than a mile from the D. S. C. I. furnace. There was no contamination of smoke from the Tennessee Company's smelter.

Date	Test No.	Parts per million	Distance
Sept. 3rd,	76	.37	2,000 yards
" 4th,	77	.28	2¼ miles
" "	78	.19	Same place
" "	79	.38	2¼ miles
" "	80	.76	Near same place, 5 minutes later
Sept. 7th,	103	.28	2,000 yards
" 11th,	171	.37	3,300 yards
" "	172	.00	4,100 yards

With reference to this last test it is said: "This test should have shown gas if there was any lurking here, as

on approach it is as if the gas were hanging here and had looked so for some time" (p. 49).

The following readings were by Prof. Palmer:

Date	Test No.	Parts per million	Distance
Sept. 21st	11	.1	2,600 yards
" "	12	.00	2,600 yards
Sept. 23rd	20	.00	2 miles
" 27th	23	3.3	3,900 yards
" "	24	.8	3½ miles
" "	25	.8	4¼ miles, but it is noted that "test somewhat doubtful"
" "	26	.00	5¼ miles
" "	27	.00	4½ miles
" "	28	.00	3¼ miles
" "	29	.00	1,800 yards
Sept. 28th	30	.6	1,800 yards
" "	31	2.05	1,800 yards
" "	32	1.3	1½ miles
" "	33	1.9	2¼ miles
Oct. 1st	37	.00	1¾ miles

These tests by Professor Palmer were made **under the most unfavorable conditions**; that is, on damp and foggy days, and when the limitation of escaping gas was forty tons per day. (It was agreed by the State of Georgia that defendant D. S. C. I. Co. might, from Sept. 20 to Oct. 1st, emit an amount of sulphur not to exceed 40 tons per day. Ex. A to report, p. 64).

Consideration of this table shows how rapidly the sulphur dioxide becomes diffused as the smoke travels from the furnace. For illustration, Test No. 18, which showed 335 parts of sulphur dioxide to the million was made on bunkers against wall of charging floor, and the operator was almost overcome by smoke in taking sample, while No. 19, taken at the same time, and but one hundred

feet away, showed the presence of **only 35.5 parts.** That is, in the atmosphere but one hundred feet further away there was present but about .1 as much dioxide of sulphur.

Again: Test 62, which reads 171.58, was taken "on bunkers close up to wall of charging floor," while test 62a, taken at the same time but a hundred feet away, showed 73.75. Test No. 71, taken three hundred yards from smelter, gave a reading of 5.77, while No. 72, taken five minutes later, seven hundred yards away, showed only .74.

It is unnecessary to call attention to other examples, as the fact that the dilution rapidly increased as the distance from the furnace becomes greater is specially commented upon in the report.

Much is said in the evidence introduced by the plaintiff on the last hearing with reference to the odor of the smoke. A careful consideration of these tables shows that the presence of odor is of no, or at most of but little value in determining whether or not the smoke contains sulphur dioxide. For illustration, Test 142b showed a presence of 1.86 parts of dioxide, but there was no odor; while Test 145 contained but 1.67 of dioxide but the odor was pronounced. In Test 147 no odor was present though the smoke contained 1.30 of dioxide. In Test 160 the odor was very slight though there were present 3.72 of dioxide, and in Test 162 the odor is marked slight, when there was 3.35 of dioxide present. It is not suggested in the report what element in the smoke produces the odor, but certain it is that it is not sulphur dioxide; and hence the evidence taken by plaintiff before the hearing to the effect that strong odor was present in smoke did not indicate that it was injurious to plants.

There is not a single reading taken at an equal or

greater distance than that between the Ducktown Company's plant and the Georgia line, which showed the presence of as much as one part of dioxide in a million. The only tests made at such a distance are the following, by Professor Palmer:

	No.	Parts	Distance
Sept. 27th	24	.8	3¼ miles
" "	25	.8	4½ miles, which test is designated as "somewhat doubtful," and is omitted by Dr. McGill in his comments on page 55
" "	26	.00	5¼ miles
" "	27	.00	4½ miles
" "	28	.00	3½ miles

And on September 28th Nos. 34 and 35 at 3⅛ and 3 miles respectively, each of whcih showed .1.

As stated in the report, these readings were made under the most unfavorable conditions, the weather being foggy, and the limitation upon the amount of sulphur discharged into the air being forty tons per day.

Test No. 23, made on September 27th by Professor Palmer, which shows 3.3 parts of sulphur dioxide at 3,900 yards was the most unfavorable one made, and with reference to that test, special attention is called to the following paragraph in the report:

> "Reference to the weather reports shows that the wind blew almost constantly from the southeast from the evening of Sept. 26th to noon on the 28th and very slowly except for three or four hours in the afternoon of the 27th. **The weather conditions were such as in all probability added the effects of the smoke from the Company's plant to those of the plant of the D. S. C. I. Company**

smelter. One cannot, therefore, reasonably hold the D. S. C. I. Co. wholly responsible for the 3.3 parts per million of sulphur dioxide in the air at a distance of 2¼ miles—the greatest amount found in our experiments that far away from the Company's plant that possibly might be attributed to its smoke." (p. 56).

The report says, however, that it is believed probable that under certain weather conditions that much sulphur dioxide coming from the Ducktown Company's plant alone is sometimes present in the air at that distance, but manifestly this is a mere surmise, as there was no reading to confirm it.

2nd. **The amount of sulphur dioxide escaping or likely to escape cannot injure vegetation in Georgia.**

The evidence in the record with reference to what amount of sulphur dioxide will injure plants is as follows:

In the affidavit made by Dr. Fernow, a scientist of note, which is referred to in the cross-examination of Dr. Hedgecock, the following appears:

> "In strange contrast to these practical figures is the statement of authorities (Schroedder and others) that one part in a hundred thousand inflicts great injury, and that even one in one million is injurious. The strangeness vanishes if we investigate the basis for this assertion. It is based upon laboratory experiments which in no way, physically or chemically represent conditions in the open air. These chemists overlook that the plant in these experiments is deprived of defense by removal from the natural conditions of its functions; that sulphurous anhyrid in the nascent state, as employed in these experiments, is much

more highly corrosive than the same substance under the conditions in which it is found in the fumes, and that much of the sulphur dioxide travelling through the air is changed into the less active trioxide." (Vol. 1, p. 52).

"Stoeckhardt's experiments on the other hand, showed that deciduous trees, treated in a covered glass, i. e., under conditions unfavorable to the plant, with a mixture of one in fifty thousand for weeks had no effect whatsoever, and even stronger mixtures, one in thirty thousand and one in twenty thousand repeatedly applied had no effect." (Vol. 1, p. 54).

Upon this subject Professor Bain testified:

"Q. 154. Do you know, Professor, what percentage of sulphur dioxide is injurious to plant life?

"A. The smallest percentage that the German investigations have found, within closed boxes on the European spruce, was one part to a million weight of air. This, however, is not true under natural conditions, and the more recent investigations have shown that out in the open a plant may stand very much higher percentage of sulphur doixide than that, so that the problem or question under the varying conditions in the open is very difficult to solve.

"Q. 155. What would you say would be the effect of one part of sulphur dioxide to 100,000 of air?

"A. It would depend upon the plant upon which it acted, the frequency of the application, the condition of the atmosphere, and also with respect to light and moisture." (Vol. 11, p. 595).

While the Special Commissioner does not undertake to state the exact proportion of sulphur dioxide which will

cause injury to plants, yet his conclusions based upon his observations, are more favorable to defendant than the foregoing evidence.

He says that Captain Nolde, who lives 1,200 yards northeast of the D. S. C. I. Co. smelter, has in his yard and garden nasturtiums, kudzu vines and spider flowers, which were injured by smoke on September 11th, a sample of which gave an analysis of 6.14 parts of sulphur dioxide. And with reference to the injury done the report says: **"The injury was not severe. Many of these plants escaped, and the leaves of many other plants were not injured at all."** And it is also said: "Somewhat less than the amount mentioned above (6.14) would probably injure the leaves of many plants in a moist atmosphere with frequent applications, or prolonged contact, and more would be required in a dry atmosphere.

Hence even this most unfavorable reading of 3.3 parts of dioxide at a distance of 2¼ miles affords no evidence that any injury could result to vegetation in the State of Georgia from the operation of this defendant's plant, because (1) it does not as a certainty or hardly as a probability show that such an amount of sulphur dioxide ever reaches Georgia from this smelter; (2) if such a quantity of sulphur dioxide ever floats into Georgia from this smelter it is at exceedingly rare intervals; (3) as the presence of nearly twice that amount produced but slight injury to delicate plants at Captain Nolde's, it cannot be inferred that very infrequent applications of that amount to vegetation could possible produce any injury.

3rd. **The amount of sulphur escaping from this defendant's furnace has not for a number of years exceeded, nor is there any evidence in the record or fact stated in the**

report which indicates that it will ever exceed the amounts suggested as maximums by the Special Commissioner.

In Volume 2, page 813, of the record, Mr. Lamoreaux gives the total amount of sulphur contained in the ores treated during the year 1913, as 29,783.19 tons, and also the amount of sulphur accounted for in the matte, sulphuric acid, slag and dust, as 16,680.64 tons, which left as the amount escaping into the air 13,102.55 tons, or 44% of the whole.

On pages 2 and 3 of "Supplemental Matter and Exhibits submitted upon leave granted at the hearing on behalf of Ducktown Copper Company," there is printed a table, which is Exhibit "I" to the testimony of W. F. Lamareaux, showing the amount of ore treated during the years 1910 to 1913, of all of the Company's mines now operated. Taking 44% as the basis of calculation, there was emitted daily into the atmosphere by this defendant on an average during the years 1910 to 1913 the following amounts of sulphur:

1910	26.2 tons
1911	28.21 tons
1912	38.4 tons
1913	35.91 tons

It is recommended in the report that for five months, to-wit: from May 1st to October 1st, the amount of sulphur emitted be restricted to forty tons per day, while during the remainder of the season the limitation be eighty tons per day. Therefore, the average amount during the entire year escaping daily has been **very substantially below the maximum amount recommended for the growing season.** And as it was the custom of the Company to reduce its output during the growing season even before any re-

strictions were placed about it by this Court, it is improbable that the proposed maximum of 40 tons per day has ever been exceeded during such season, except possibly on very rare occasions. This improbability is increased by the fact that the foregoing calculation is made on the assumption that 44% of the sulphur escapes, when a glance at table No. 3, appearing on page 19 of the report, shows that during the months of June to November, 1915, the monthly averages of the per cent of escaping sulphur was much below 44 per cent, except for the month of November, when the per cent was greater on account of certain unusual and peculiar conditions.

III.

The suggested limitation that the sulphur content of gases escaping be not permitted to exceed forty-five per cent of the sulphur in the green ore subjected to smelting is contradictory to the report.

It is difficult to understand why this recommendation is made. It is shown in the report (pp. 19 and 20) that while the per cent of sulphur escaping is very rarely in excess of forty-five per cent, yet there are times when it is practically impossible to keep the per cent within that limit. The damage to vegetation depends upon the amount of sulphur fumes emitted into the air, and not upon the per cent of the sulphur escaping. The report shows that, notwithstanding the average per cent of sulphur escaping during the month of November was 48.78, yet on but two days during the month were more than forty tons of sulphur emitted.

Table 1 on page 6 of the report shows that the ore from the Mary Mine contains 19.33% of sulphur; that from the East Tennessee Mine but 12.15%; while the ore from

the Isabella Mine contains 31.66%. Suppose the furnace were charged one day entirely with ore from the East Tennessee Mine and on the following day with ore from the Isabella Mine. If on the first day no sulphur were saved yet it would be necessary on the second day to eliminate about sixty-two per cent of the sulphur, to reduce the amount escaping to that which was released into the air the first day. Yet under this recommendation the same precautions would have to be exercised on the first day as to the per cent of sulphur escaping as upon the second.

IV.

Upon all the facts a final decree should be entered dismissing the case as to the defendant Ducktown Sulphur, Copper and Iron Company.

The case should, therefore, be dismissed as to this defendant, because:

(1) The report shows conclusively that which was insisted on the last hearing, that this defendant has faithfully and at very great expense made every endeavor to reduce the amount of sulphur emitted into the atmosphere to a minimum, and that such efforts still continue. This is done not only to conform to the orders of this Court and to prevent injury to vegetation, but because it has been ascertained that the by-products obtained from the smoke fumes can be manufactured profitably, which creates a motive that insures no relaxation in the endeavor.

(2) The recommendation that to some one should be assigned the duties of watchfulness and precaution with reference to diminishing the quantity of sulphur escaping when atmospheric conditions change, and that the Company should be required to keep a daily record showing the

amount of material treated and the percentage of copper, iron and sulphur therein, and the results of treatment and of weather conditions, should not be incoporated in a decree, because the testimony of Mr. Lamoreaux shows that such records are now being and have been for many years kept and preserved, and they would of course be accessible by orders of any Court in case any litigation should hereafter arise; and furthermore, there is nothing in the report or in the record to indicate the necessity of the preservation of such data, or the probability of its becoming valuable, **and it would entail a continuous supervision of the defendant's business by this Court.**

(3) The recommendation that the total sulphur content of gases escaping from May 1st to October 1st be limited to forty tons per day for two consecutive days and to eighty tons per day for two consecutive days during the remaining months of the year, and that further restrictions of the sulphur content of escaping gases be imposed when atmospheric conditions are unfavorable, should not be incorporated in a decree, because:

(a) It is shown by the report and by the evidence that such limitations have not been exceeded for a number of years, unless it be on rare occasions, and that there is no probability of the defendant's ever materially exceeding the amounts stated.

(b) The report shows that the quantities stated can be materially exceeded and yet no injury, or but slight injury, done to vegetation, even in the vicinity of the furnaces.

(c) The report conclusively shows that the amount of sulphur emitted by this defendant's furnace since the construction of the acid plant has not been of such quantity as to affect injuriously vegetation in the State of Georgia,

and there is nothing in the facts stated in the report to suggest that this defendant's furnace will ever be operated in such a way as to do damage to the forests and crops in the State of Georgia.

(4) The suggested limitation that the sulphur content of gases escaping should not exceed forty-five per cent of the green ore subjected to smelting should not be incorporated in a decree, because:

(a) This restriction is wholly unnecessary, as the injury to vegetation depends upon the amount, and not upon the per cent of the sulphur escaping into the air, and it is inconsistent with the previous recommendation.

(b) As above stated the Special Commissioner finds no facts from which an inference can be drawn that defendant's furnace will be so operated in the future as to cause any damage to forests or crops in the State of Georgia.

(5) The other restrictions suggested are not germane to the matters here in litigation, as they have no bearing upon the effect of smoke fumes in Georgia.

(6) To enter a decree containing the provisions recommended would in a manner place defendant's business under the continuous supervision of this Court, and Courts of Equity do not interfere further than is necessary in the conduct of private business.

V.

Authorities in Support of Defendant's Contention

The attention of the Court is again called to the authorities which were relied upon on the hearing at the last term, which are as follows:

On the original hearing the Court said:

"The caution with which demands of this sort, on the part of a state, for relief from injuries analogous to torts, must be examined, is dwelt upon in Missouri vs. Illinois, 200 U. S., 496, 520, 521;" and the Court stated its conclusions from the evidence presented as follows:

"Without any attempt to go into details immaterial to the suit, it is proper to add that we are satisfied, by a preponderance of the evidence, that sulphurous fumes cause and threaten damage on so considerable a scale to the forests and vegetable life, if not to health, within the plaintiff state, as to make out a case within the requirements of Missouri vs. Illinois, 200 U. S., 496." (206 U. S., 237, 238).

In **Missouri vs. Illinois,** 200 U. S., 521, the Court said:

"Before this Court ought to interfere, the case should be of serious magnitude, clearly and fully proved, and the principle to be applied should be one which the Court is prepared deliberately to maintain against all consideration on the other side. See **Kansas vs. Colorado,** 185 U. S., 125." (200 U. S., 521).

The bill filed by the State of Missouri was dismissed because it was not clearly shown by the evidence that the water of the Mississippi was materially contaminated by the sewage discharged into it from the City of Chicago.

It is furthermore well recognized that the Courts should proceed with the greatest caution in determining whether an obstruction or certain acts constitute a public nuisance, and should not extend their decrees with reference thereto beyond the facts clearly proven. In High on Injunction, Section 760, it is said:

> "But to warrant an injunction against an alleged purpresture or public nuisance, it must clearly appear that it is such in fact, and if it be doubtful whether there is a purpresture the relief will be withheld."

Attorney General vs. Deleware and Bound Brook R. R. Co., 27 N. J. Eq., (12 C. E. Green) 1, was an action brought to have removed a viaduct built across a navigable river on the ground that the structure was a purpresture and public nuisance. The Court held that:

> "If it were merely doubtful whether there is a purpresture or not, an injunction asked for on the ground of purpresture will not be granted. To warrant an injunction in such a case it must be clear that there is a purpresture."

And again:

> "In an action to remove an erection in a public river on the ground that it is an injury to the **jus publicum,** the common right of navigation, it must appear that a nuisance, in fact, exists, even though the erection be an encroachment on the soil of the State."

This Court has declared this principle with even greater emphasis. **Mississippi & Missouri R. Co. vs. Ward, 2 Black,** 485-495, was an action brought by a private individual to have abated an alleged public nuisance, to-wit, a bridge over the Mississippi River. The Court in the first place held that under such circumstances the private party acts rather as a public prosecutor on behalf of all who are or may be injured; and with reference to whether that part of the bridge within the jurisdiction of the Court below was a public nuisance, the Court said:

"Is the bridge west of the Illinois boundary an **unreasonable** obstruction, and therefore a nuisance? In considering this question we must be governed by the same rule on which a court of law could proceed in case of an indictment against the bridge company for committing the nuisance; and the rule is that if the abridgement of the right of passage occasioned by the erection was for a public purpose and produced a public benefit, and if the erection was in a reasonable situation, and a reasonable space was left for the passage of vessels on the river, then it is not an unreasonable obstruction and indictable. Rex vs. Russel, (6 Boren & Crews, 566; 13 How., 623; 15 Wendell, 133).

"Then, again, the obstruction to navigation must be plainly a nuisance within this rule before it can be removed by decree. If the proceeding was by indictment and the jury doubted whether the obstruction was a nuisance or not, they would be bound to acquit, and the same rule applies in a Court of Chancery when the Court ascertains the fact of nuisance. 2 Storey's Com. on Eq., 203-204."

In actions brought to enjoin the maintenance of a nuisance, if the defendant ceases to maintain the nuisance at any time while the case is within the jurisdiction of the Court, and it is apparent that its resumption is not intended by the defendant, a decree of injunction will be denied.

1 High on Injunctions, (4 Ed.) Sec. 572; Trulock vs. Merte, 72 Ia., 510-513; Perry vs. Howe Co-operative Creamery Company, 125 Ia., 415-417; McCarthey vs. Gaston Ridge Mill, etc., Co., 144 California, 542-546; King vs. Morris & Essex Railroad Company, 18 N. J. Eq., 397, 399,

400; Arizona Copper Company vs. Gillespie, 230 U. S., 46, 55, 57.

For the foregoing reasons the original bill should be dismissed as to the defendant Ducktown Sulphur, Copper & Iron Company, Limited.

W. B. MILLER,

J. A. FOWLER,

Solicitors for Defendant D. S. C. I. Co., Ltd.

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Supreme Court of the United States

October Term 1915

No. 1.—Original

IN EQUITY

THE STATE OF GEORGIA, *Complainant*

vs.

THE TENNESSEE COPPER COMPANY AND THE DUCKTOWN SULPHUR, COPPER AND IRON COMPANY, LIMITED, *Defendants*

FORM OF INJUNCTIVE DECREE AGAINST THE DUCKTOWN SULPHUR, COPPER AND IRON COMPANY, LIMITED.

CLIFFORD WALKER,
MARK BOLDING,
J. A. DRAKE,
LAMAR HILL,
Solicitors for Complainant.

SUPREME COURT OF THE UNITED STATES.

OCTOBER TERM, 1915.

THE STATE OF GEORGIA, *Complainant,* *vs.* THE TENNESSEE COPPER COMPANY AND THE DUCKTOWN SULPHUR, COPPER & IRON COMPANY, LIMITED, *Defendants.*	No. 1 Original, In Equity.

Comes now the complainant in the above entitled cause, by its counsel, and respectfully represents to the Court:

That, at the October Term, 1914, of this Honorable Court, an order was entered in this cause perpetually restraining and enjoining the defendant, the Ducktown Sulphur, Copper & Iron Company from using, managing or operating any furnace, pit or oven for reducing copper ore which causes or gives off poisonous, noxious or unwholesome gas, vapor or fume, except upon certain terms and conditions therein named, and appointing an inspector therein named to make observations of conditions in the territory adjacent to the plant of said defendant and to make report and recommendations to the Court at the end of six months from the date of the decree, and retaining the cause for further action upon proper application by either party.

That the report of said inspector has been filed and complainant respectfully submits, demonstrates that the decree of injunction heretofore granted should be continued and renewed, and therefore,

Complainant submits herewith a form for final decree of injunction in said cause.

CLIFFORD WALKER,
MARK BALDING,
J. A. DRAKE,
LAMAR HILL,
Solicitors for Complainant.

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The complainant, having moved the Court to enter an injunctive decree against the Ducktown Sulphur, Copper & Iron Company, Limited, in conformity with the decrees of the Court heretofore entered, and it now appearing that the defendant, The Ducktown Sulphur, Copper & Iron Company, Limited, its officers, servants, agents and employees under its control are guilty of the acts complained of in the smelting of its copper ore, and that its plant as conducted is injuring and damaging complainant and its citizens by discharging poisonous, noxious and unwholesome fumes and gases which are carried by the air currents over the territory of the State of Georgia:

It is now here ordered, adjudged and decreed that said defendant, The Ducktown Sulphur, Copper & Iron Company, Limited, its officers, servants, agents and employees are hereby perpetually restrained and enjoined from so using, managing, maintaining, or in any manner operating any furnace, pit, oven, or other appliance or cop-

per-reducing method which causes, generates, gives off or discharges any poisonous, noxious, or unwholesome gas, vapor or fume, causing, permitting or allowing the escapement into the air of fumes carrying more than forty-five per cent. of the sulphur contained in the green ore subjected to smelting; or permitting or allowing the escapement into the air of gases, the total sulphur contents of which shall exceed twenty tons during one day from April 10th to October 1st of each year, or exceed forty tons in one day during any other season.

It is further ordered, adjudged and decreed that the said complainant do recover of the defendant, The Ducktown Sulphur, Copper & Iron Company, Limited, its costs in this suit to be taxed.

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Supreme Court of the United States

October Term 1915

No. 1.—Original

IN EQUITY

THE STATE OF GEORGIA, *Complainant*

vs.

THE TENNESSEE COPPER COMPANY AND THE DUCKTOWN SULPHUR, COPPER AND IRON COMPANY, LIMITED, *Defendants*

OBJECTIONS OF COMPLAINANT TO MOTION TO DISMISS THE CASE AS TO IT OF THE DUCKTOWN SULPHUR, COPPER AND IRON COMPANY, LIMITED.

CLIFFORD WALKER,
MARK BOLDING,
J. A. DRAKE,
LAMAR HILL,
Solicitors for Complainant.

SUPREME COURT OF THE UNITED STATES.

OCTOBER TERM, 1915.

THE STATE OF GEORGIA, *Complainant,* *vs.* THE TENNESSEE COPPER COMPANY AND THE DUCKTOWN SULPHUR, COPPER & IRON COMPANY, LIMITED, *Defendants.*	No. 1 Original, In Equity.

OBJECTIONS OF COMPLAINANT TO MOTION TO DISMISS CASE AS TO IT OF THE DUCKTOWN SULPHUR, COPPER & IRON COMPANY, LIMITED.

Comes now the complainant, by its counsel, and by leave of the court first had and obtained, files these, its objections to the motion of the defendant, the Ducktown Sulphur, Copper & Iron Company, Limited, to dismiss said cause as to it, and says:

That, at the October Term, 1915, of this Honorable Court, an opinion was handed down in which it was held that the efforts of the defendant, the Ducktown Sulphur, Copper & Iron Company, Limited, to show that conditions in the alleged affected territory in Georgia had changed and that no material damage was being done had been unsuccessful, and that on the contrary, damage was being done, and that the complainant was therefore entitled, upon its original petition in this Court, to a final decree of injunction against this defendant.

The opinion further declared that the evidence not only unquestionably demonstrated the fact that damage was being done, but also that the total sulphur content of the gases and fumes emitted from the plant of the defendant was substantially thirty tons per day and that this amount "*produces harmful results and must be diminished,*" and directing the appointment of a competent inspector to observe the operation of the plant during the succeeding six months and make report to the Court with recommendations as to the total sulphur content of the gases, etc., to be allowed in future.

Upon this opinion a decree was formulated embodying the findings of the Court and giving to complainant a permanent injunction against this defendant, and appointing Dr. John T. McGill as the inspector.

Complainant respectfully submits that the only purpose of the appointment of Dr. McGill was for the assistance of the Court in arriving at an exact limit to be put upon the operations of this defendant and the total sulphur content of gases emitted, to be allowed, *under the thirty tons per day,* which the Court said was harmful.

And Dr. McGill himself, in his report, does not recommend the dismissal of the cause, as is sought by the defendant, but in effect recommends that the injunction be continued in force imposing certain restrictions and limitations upon the defendant in the operation of its plant.

The question of the allowance of an amount in excess of thirty tons per day is res judicata as is every question of fact submitted to the Court. Virtually the same evidence was introduced by the defendant by its experts in the taking of testimony and on which the Court passed, as is now submitted by Dr. McGill and the facts therein sought to be proved are res judicata.

In view of the fact that the Court had adjudicated in its original decree every question of law in this case and that in its decree of May 10, 1915, it has actually granted a final decree of permanent injunction against this defendant, it is respectfully submitted that defendant cannot, at this time, ask a dismissal by the Court of the cause which has been finally determined adversely to it, and the only question now before the Court is as to the form of the decree to be rendered by it and the limitation, under thirty tons per day, to be put upon the defendant, and complainant has presented its motion to the Court for such decree.

CLIFFORD WALKER,
MARK BOLDING,
J. A. DRAKE,
LAMAR HILL,
Solicitors for Complainant.